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GEOPHYSICS

A Journal of General and Applied Geophysics

Published by

The Society of Exploration Geophysicists

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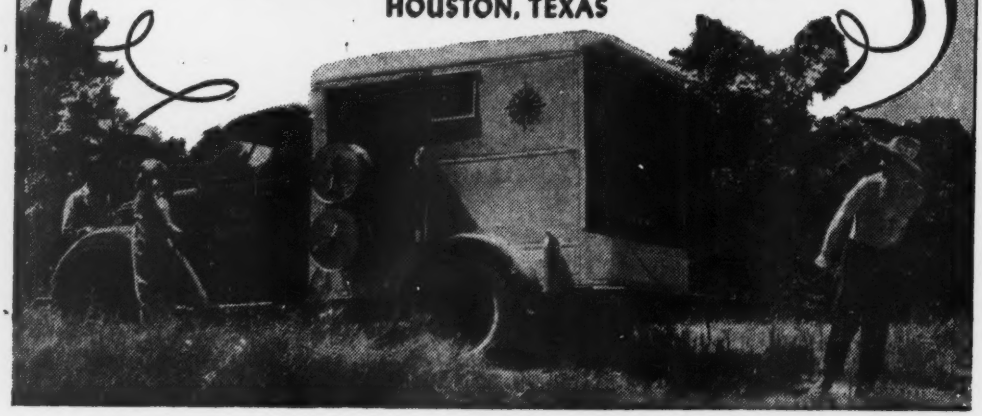

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GEOPHYSICS is the official publication of the Society of Exploration Geophysicists and is published four times a year, January, April, July and October. $3.00 ($3.50 foreign) of the annual dues is set aside for payment of the annual subscription to the Society Journal, GEOPHYSICS. The subscription rate to non-members is $6.00 per year (plus 50 cents additional for postage to foreign addresses).

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The Society of Exploration Geophysicists

Society: The Society of Petroleum Geophysicists was organized in 1930 at Houston, Texas. In 1936, the Society approved a change in name to the Society of Exploration Geophysicists, to indicate the close association of the aims and objects of the Society with the newly recognized primary function of Exploration, which had recently been recognized by the petroleum industry as being on a par with Production, Transportation, Refining, and Marketing.

Aims and Objects: The Society functions for the promotion of the science of geophysics, especially as it relates to petroleum geology and to the discovery and production of oil and natural gas and associated minerals, and the maintenance of a high professional standard among its members. Among the methods of accomplishing these objectives is the publication of papers, discussions, and communications of interest to the membership.

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Special care should be given to mathematical expressions. The very simplest formulas only should be typewritten and all others carefully written in with pen and ink. Fractional exponents should be used everywhere to avoid root signs. Extra symbols should be used to avoid complicated exponents. The solidus (/) should be used wherever possible for fractions.

All illustrations should accompany manuscript and should always be referred to in the text. Line drawings must be made with India ink on plain white paper or on tracing cloth. Coordinate paper is not desirable, but if used must be blue-lined with all coordinates to be reproduced drawn with India ink. Lettering should be of sufficient size to be legible after reduction. Captions for all Figs. should be submitted on a separate sheet and not included in the drawing. For detailed instructions on the preparation of manuscript and illustrations for GEOPHYSICS, see paper by Nettleton in Vol. X, No. 3 (July 1945), pages 421 to 428.

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L. L. NETTLETON, *Editor*
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Society of Exploration Geophysicists

Change of Address

THE OFFICES of the Society are being moved this month, due to resignation of Miss E. Stiles as business manager, to Tulsa, Oklahoma, where it is expected permanent headquarters will henceforth be maintained. All correspondence other than editorial matters (Dr. L. L. Nettleton, Editor, 1348 Mellie Esperson Bldg., Houston 2, Texas) should be addressed, from this date, to

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12-F and 12-G SEISMOMETERS

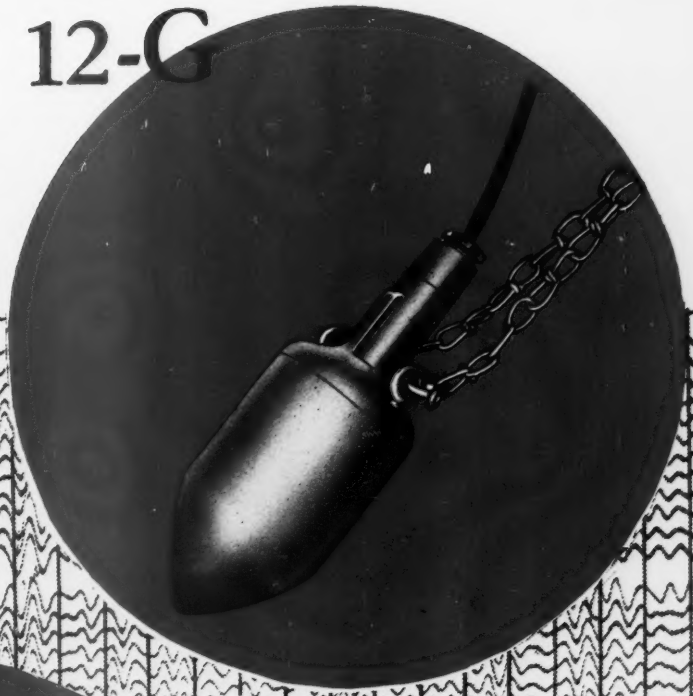
Folder No. 4

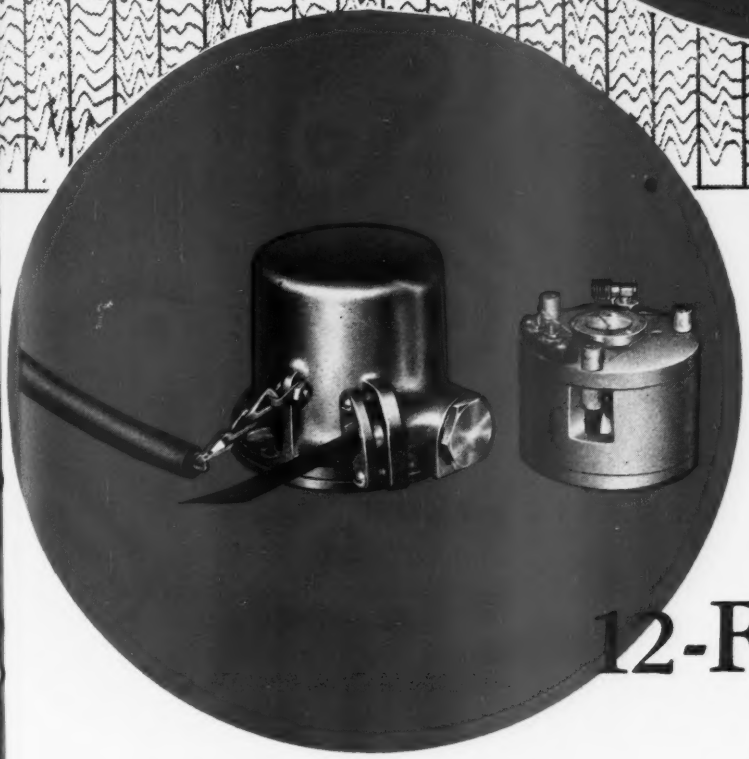
SEISMOMETERS

The National 12-F seismometer is an integral part of the National 25-A seismograph, and one, two, or three of these seismometers, depending upon the requirements of the survey, are used for each of the 24 amplifiers. This seismometer, which is of the dynamic type with the moving coil element used as the spring-supported mass, is electromagnetically damped and contains no fluids. It is of all-metal construction except for the electrical terminal mounting insulation and is hermetically sealed. The undamped natural frequency of the seismometer is approximately eight cycles per second. Its damping, which is entirely electrical, is sufficient to provide a velocity response which is essentially flat from 25 to 400 cycles. The National 12-F seismometer has been designed for use in surveys which are made on land.

The National 12-G seismometer is identical, except for the case, with the National 12-F seismometer. This seismometer has been especially designed for use in surveys where the instrument must be used beneath the water. The case is exceptionally strong and will withstand greater pressure without developing any leakage. The characteristics of the instrument are the same as those of the National 12-F seismometer.

12-G





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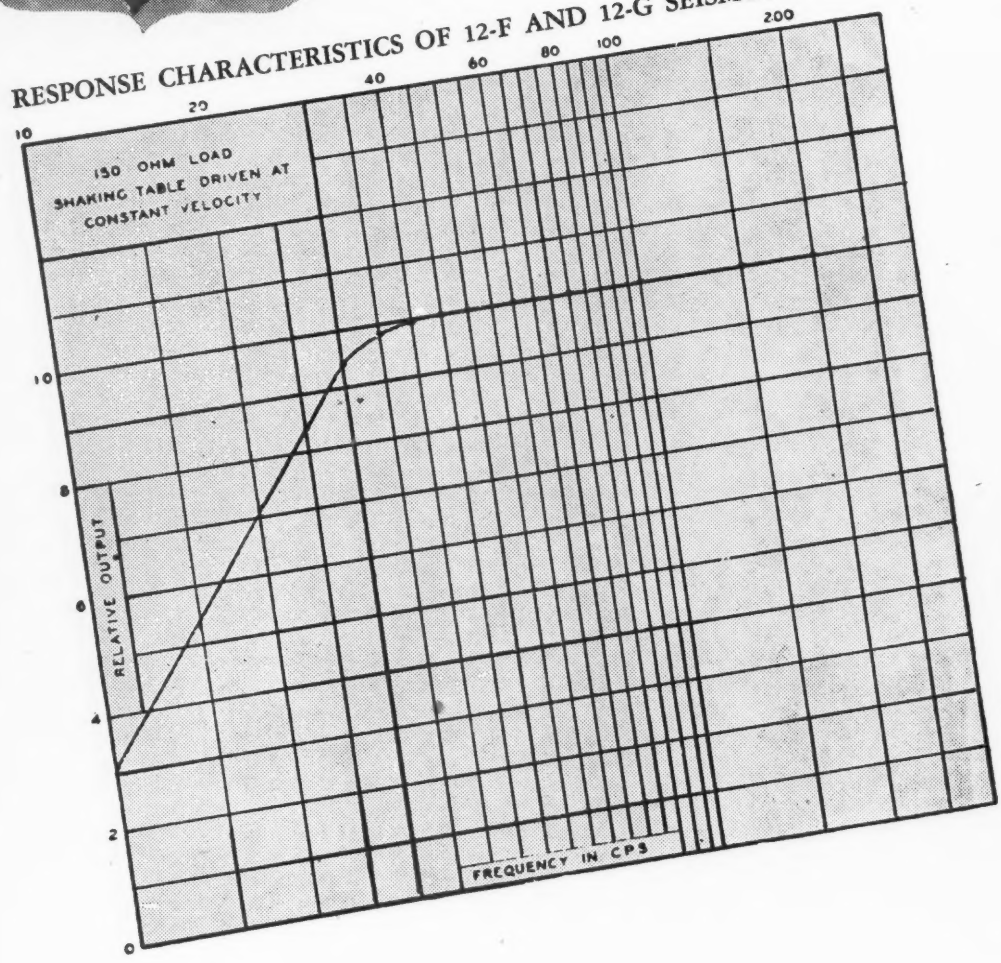
RESPONSE CHARACTERISTICS OF 12-F AND 12-G SEISMOMETERS



SPECIFICATIONS

12-F SEISMOMETER

Natural frequency—8 c.p.s.
Damping—electromagnetic
Response characteristic—
See above graph
Internal impedance—150 ohms
Sensitivity (150-ohm load) — $1x10^{-3}$ volts/mil/sec
Weight—5 pounds
Size—diameter 4", height 4"

12-G SEISMOMETER

This seismometer is the same as the type 12-F seismometer with the exception of the case. The 12-G seismometer has an especially designed, bullet-shaped case for use in swamp or water work.
Weight—7¼ pounds
Dimensions—
Height 11", diameter 3 15/16".

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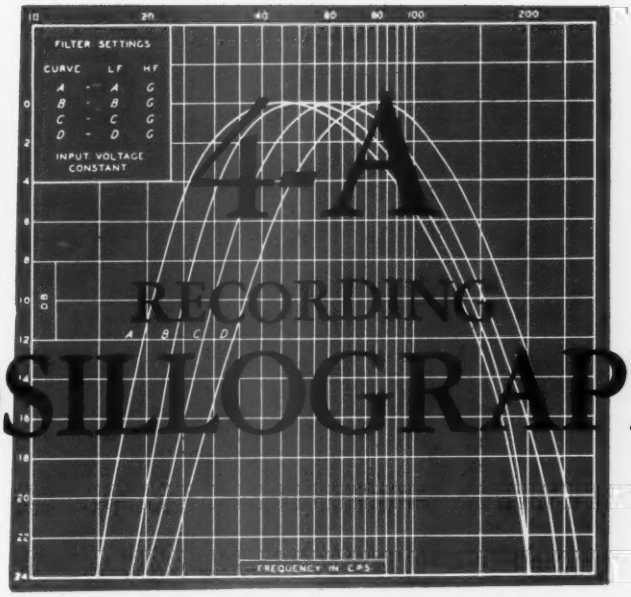

Folder No. 5

National 4-A

R E C

S C I L

The recording oscillograph that is provided as standard equipment with the National 25-A seismograph comprises 24 mirror-type galvanometer units, highly sensitive, electromagnetically damped, and flat in frequency response over the seismic reflection range. The timing system incorporates a vacuum tube driven tuning fork, and a synchronous timing line motor. The recording paper is driven through the camera by means of a synchronous motor, insuring a constant paper speed. The camera is designed for use with recording paper of any width up to 10 inches.

SPECIFICATIONS

Recording elements—24
Damping—electromagnetic
Galvanometer size—diameter 1/4", length 3 1/2"
Galvanometer weight—0.33 ounces
Natural frequency—240 cycles
Paper drive—synchronous motor
Paper magazine—capacity, 200-foot roll of any width up to 10 inches
Timing—synchronous motor driven by tuning fork
Dimensions—13"x21 1/8"x8 3/4"
Weight—55 pounds

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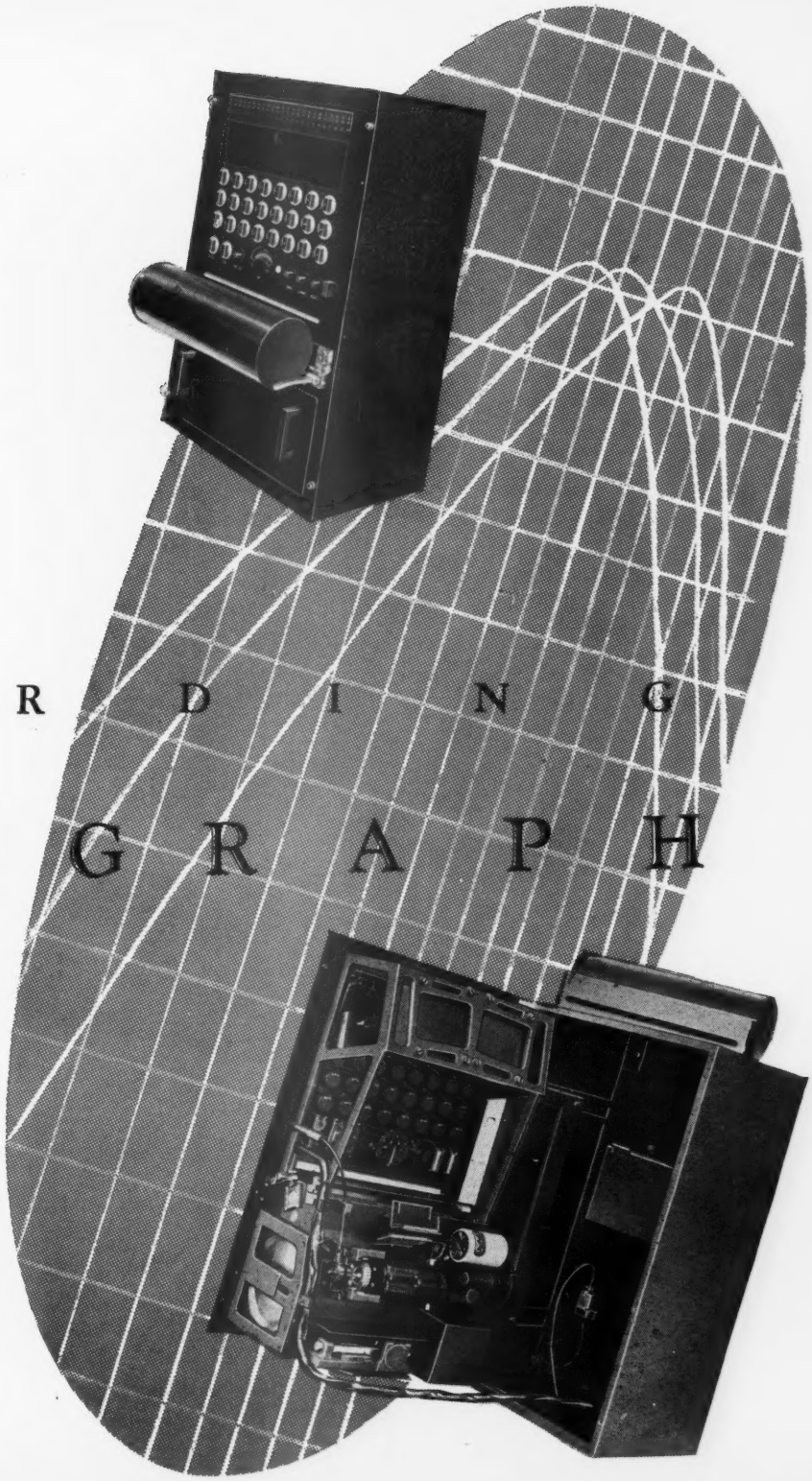

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TEST ROOM

The precision with which the National instruments are made requires the use of an electrically screened test room (shown above) for their final laboratory adjustment. Despite this precision in adjustment these instruments are extremely stable under field operating conditions and give little or no repair trouble.

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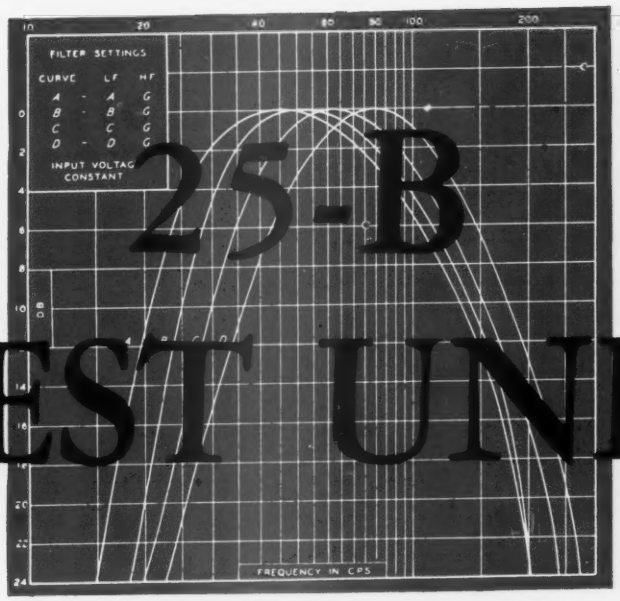

25-B TEST UNIT

This unit is a new addition to the Nationa equipment. All testing devices used in the op eration of the equipment have been located i one panel for ease and convenience of testing

This panel provides:

Equipment for testing the continuity and resistance of the cable and seismometer circuits.

Balancing circuits to minimize or eliminate interference from power lines.

A test signal generator for use in checking the performance of amplifiers, compositing panel and oscillograph under actual operating conditions.

Signal source for the operation of a portable device used in the location of short circuits and open circuits in the seismometer cables.

SPECIFICATIONS

Weight—27½ pounds

Dimensions—13½"x20¼"x11 15/16"

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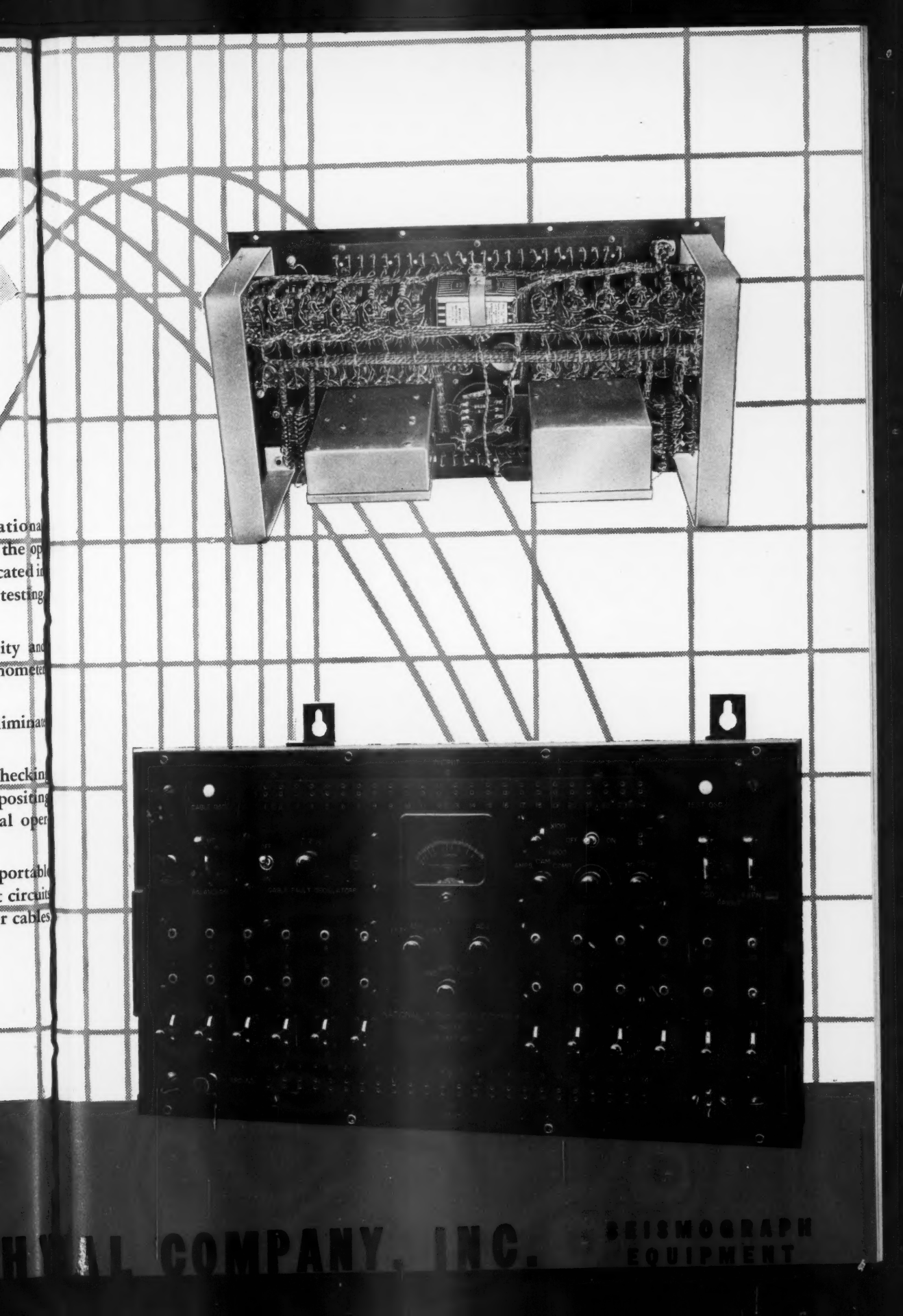
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EQUIPMENT

Amplifier Maintenance Department

It has been the policy of National to make all repairs and adjustments to the amplifiers in the Amplifier Maintenance Department (shown above) of their laboratory. This policy requires amplifiers which are so designed that they give long trouble-free service under severe field conditions. The repair of the amplifiers in the central laboratory with experienced personnel and precision testing equipment insures the maintenance of their high quality of operation.

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VOLUME XI JULY, 1946 NUMBER 3

GEOPHYSICS

A Journal of General and Applied Geophysics

PUBLICATION OF GEOPHYSICAL CASE HISTORIES[1]

HENRY C. CORTES[2]
Dallas, Texas

As an introduction to the subject, I wish to review certain aspects pertaining to exploration and to the history of the Society of Exploration Geophysicists.

Prior to about 1925 economic geologists found many well-marked virgin surface structures in North America. Predictions were made, and later confirmed, as to structural uplift and closure; and in numerous cases, predictions as to probable oil production were also confirmed. Shortly thereafter, in those areas which had been mapped geologically, using E. DeGolyer's simile, the more apparent big fish had been caught in the surface geology net and new arts were needed to seine deeper.

In an overlapping period exploration geophysics was started in the United States, torsion balance gravity work in 1922, and refraction seismograph in 1923. Many domal uplifts were quickly found, most of these having little or no apparent expression in the surface beds. The majority of these are now producing oil or gas. The torsion balance has accounted for many shallow, medium depth, and some deep salt domes. Mainly due to greater speed, gravimeters have almost completely replaced torsion balances, and numerous oil fields owe their discovery, either fully or partially, to interpretation of anomalies shown by this method. Through refraction seismograph work predic-

[1] Presidential address, Society of Exploration Geophysicists, delivered in Chicago, April 2, 1946, before Joint Annual Meeting of this Society, the American Association of Petroleum Geologists, and the Society of Economic Paleontologists and Mineralogists.

[2] Director, Geophysical Exploration, Magnolia Petroleum Company.

tions have been made as to the location and depth of shallow and medium depth salt domes; and drilling has confirmed the depth and extent of the cap rock or salt. Later, in the case of the reflection seismograph, predictions made as to amount and area of closure, and as to depth of producing zones, were verified by drilling. Magnetometer results have indicated some igneous plugs and other anomalies directly, and helped to delineate the regional basement trends and to indicate basement depths. In addition, progress is being made in geochemical and electrical prospecting methods, and these hold promise for the future, though they have not approached the economic state of the other methods.

Since the founding of S.E.G. in 1930, one of the main themes of our retiring presidents has been that of encouraging co-operation between geophysicists and geologists in our duty of finding new oil reserves. Happily, co-operation has been attained.

Full co-operation is more essential now than ever before because of interpretation, or attempted interpretation, of the pinchout and lenticular type of stratigraphic traps, closures associated with faults, and overthrusts. Now, maximum ingenuity must be used to discover new arts, as well as to improve present methods suitable for such exploration. It is considered possible but not probable that novel exploration methods will be developed as a result of wartime inventions.

There are two principal reasons for the formation, present existence, and future being of The Society of Exploration Geophysicists. The first, mainly intangible, is the value one receives from the joint annual meetings. By that is meant information acquired from manuscripts that are read, from accompanying discussions, and in personal contacts with old friends and new. The second reason, a tangible one, is our journal GEOPHYSICS. Neither the annual meetings nor the Society would have flourished without the other. Few exploration geophysicists feel the natural urge to write manuscripts unless, as a result of the extra study and preparation, they are given the privilege of delivering the paper orally. In that manner the author himself receives additional benefits from the discussion period that follows. The same holds true for A.A.P.G. and S.E.P.M.

The majority of the manuscripts published in the past by S.E.G. members relate to pure research, to the results of applied research and development as concerns instrumentation, to field techniques, and to office interpretational methods. This is the natural course of publi-

cation on the geophysical methods which have been in use twenty-four years in the United States.

Here, let us pause and ask if the labors of the authors and of the officers of S.E.G. have been justified in the publication of our Journal; that is, justification to themselves, to the Society, to the annual meetings, and, last but not least, for the companies, large and small, who pay the expenses of the majority of those who attend the meetings. No doubt an emphatic affirmative answer is due. The same answer, with equal emphasis, may be given as to the A.A.P.G., S.E.P.M., and to the companies who pay the expenses of their members attending the annual meetings. I wish to emphasize the answer as it relates to the number of representatives the various companies send to annual meetings, the cost the companies incur, and the number of papers their employees present orally and by publication. The managements of some companies are more liberal than others, both as to attendance and as to papers contributed by employees. I think we may say to every company that whether it sends few or many representatives to the meetings, whether its employees have contributed one or a number of papers, each company receives many times the value for both the time and the money invested, in both tangible and intangible results. No one company, at the present time nor in the past, has equalled the research and development of the combined total of all the others.

Now, however, sixteen years after our Society's organization and publication, two results are to be recognized. First, instrumentation, field technique, and interpretation have reached a rather stable and advanced stage under our present conception of seismic, gravimetric, and magnetic instruments. Second, sufficient drilling has been done as a result of geophysical and combined geophysical-geological work whereby the time is ripe for publication of geophysical case histories.

It is my desire, on behalf of our Society and its officers, to urge the full support, not only of our S.E.G. membership, but also that of A.A.P.G.–S.E.P.M. officers and their members, in the publication of "Geophysical Case Histories." This volume will be analogous to the two volumes which the A.A.P.G. published under the title "Structure of Typical American Oil Fields."

The Executive Committee of S.E.G. has authorized publication and has appointed Dr. L. L. Nettleton, very able Editor of our journal GEOPHYSICS, as Editor of what we hope and expect to be the first of several volumes.

Including the five case histories given at this Chicago meeting, and one "read by title," we now have a total of twenty-six contributions consisting of approximately 375 pages—or roughly one-half the material required for the first volume.

Eighteen oil companies maintain their own staffs to design and manufacture their own geophysical equipment. There are approximately fifteen who regularly, and many others who intermittently, use the services of more than fifty contract geophysical companies. This does not include American companies doing geophysical work in foreign countries. Surely, in the files of all these oil companies there is more than adequate material which can and should be made available for the first volume.

The contents will be of great value to management, geologists, geophysicists, and to others in the oil companies. Our universities and colleges, especially those teaching subjects related to exploration, will be able to use the volume to good advantage. We have already had requests for, and have furnished, large scale maps and other data for such classroom use.

In soliciting such case history manuscripts for this annual meeting we have in some instances encountered resistance. One point of objection is that a given oil or gas field has not been fully developed and the information might be used adversely. In such cases, by using only a dashed line showing the approximate area of production, by using no section or survey lines, and no land ownership names, this objection can be overcome. The second objection is that everyone is very busy. The companies should encourage publication for the mutual benefit of employer and employee; in addition, writers are willing to work after office hours.

In summary:

1. The need exists for publishing more geophysical case histories. Such histories are essential to management, geologists, geophysicists, especially the younger ones, and for use by professors and students in universities and colleges.

2. A plan can be followed which insures that no information the company desires to withhold will be released, and no legal difficulties encountered. Every oil company has benefited by, and no company which contributed to the two A.A.P.G. typical oil field volumes has suffered from such contribution. Geophysical volumes should have a similar benefit, and no adverse effects.

3. One-half of the material is available in printed form at the pres-

ent time for the first volume. More than sufficient case history data are in the files of oil companies, and can be readily assembled. A prompt contribution of at least one case history each from the thirty-three oil companies referred to above will be sufficient to complete the first volume.

4. This is, therefore, an urgent request to the members of the three societies, and through them to their companies, for prompt co-operation so that our first volume may be published soon. I believe the services our Society has rendered in the past to every oil company merit such co-operation.

GEOPHYSICAL HISTORY OF THE LA GLORIA FIELD, JIM WELLS AND BROOKS COUNTIES, TEXAS*

WILLIAM C. WOOLLEY†

ABSTRACT

This paper presents a historical record of the geophysical activity in the area of the La Gloria Field.

The successive stages of geophysical exploration were: Torsion balance survey 1934–1935; correlation reflection seismograph survey 1936; dip reflection seismograph survey, 1938; correlation reflection seismograph survey, 1938; gravity meter survey, 1943–1944.

The discovery well, Magnolia's Sam Maun No. 1, was drilled and completed in 1938–1939, producing initially 165 barrels per day of 65° gravity distillate and 5,646,000 cubic feet of gas through a 5/16 inch choke.

Oil and gas in the La Gloria Field are being produced from sands in the Frio formation of Oligocene age. There are a number of sands producing gas-distillate. Several flank wells produce oil. The field has been unitized and a cycling plant is engaged in processing the gas-distillate.

The object of this paper is to show the growth of our geophysica knowledge of the La Gloria Field by the application to the area of various methods of geophysical exploration. Fig. 1 shows the geographical location of the La Gloria area and its relationship in southwest Texas to the Gulf of Mexico, the city and towns of Corpus Christi, Alice and Hebbronville; the producing fields of Agua Dulce and Seeligson; and the Palangana, Piedras Pintas and Falfurrias or Gyp Hill salt domes.

The chronological stages in the geophysical exploration were:

1. Torsion balance survey by a Magnolia Petroleum Co. crew, 1934–1935.
2. Correlation reflection seismograph survey by an Independent Exploration Co. crew for Magnolia Petroleum Co., 1936.
3. Dip reflection seismograph survey by a Magnolia Petroleum Co. crew, 1938.
4. Correlation reflection seismograph survey by a Magnolia Petroleum Co. crew, 1938.
5. Gravity meter survey, done as part of a regional survey, by a Coastal Oil Finding Co. crew for Magnolia Petroleum Co., 1943–1944.

* Presented at the sixteenth annual meeting, Chicago, Illinois, and at the Regional Meeting, Houston, Texas, April, 1946.

† Magnolia Petroleum Company, Dallas, Texas.

1. In 1934–1935 a Magnolia Petroleum Co. torsion balance crew under W. E. Brogan, party chief, used two, Z beam, Bamberg torsion balances to make a regional survey which included the La Gloria area; the results (gradients only) are shown in Fig. 2. Station locations were approximately 500 meters apart. The original gradients are shown with no subtraction of the regional effect. The results indicated a

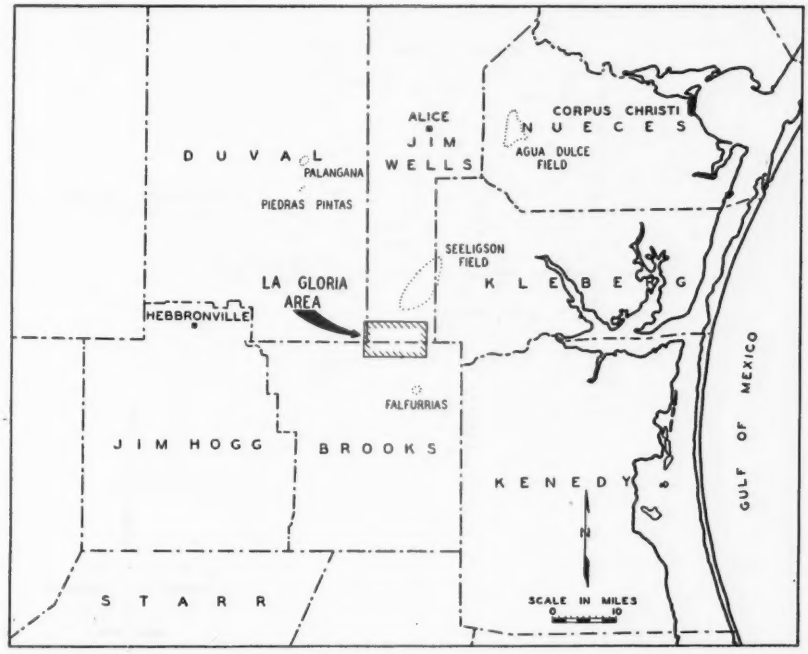

FIG. 1. Index Map of Southwest Texas showing location and extent of area covered by geophysical surveys in the La Gloria Area. Dotted lines outline major producing areas and salt domes.

northeast-southwest minimum axis with a southeast gravity nose. On this and successive figures the location of the discovery well is shown with the appropriate symbol and the approximate outline of production is shown with a dashed line. The north-south reversal of the gradients occurs approximately at the center of the producing area.

2. The first seismograph work done for Magnolia Petroleum Co. was done in 1936 by the Independent Exploration Co.'s reflection Party No. 5 under John H. Crowell, party chief. The area was worked

with shot points approximately 2000 feet apart. These are shown as small circles (Fig. 3). Three spread lengths, one a 400 foot split spread, a 600 foot to 1400 foot spread and a 1600 foot to 2400 foot spread were shot in two directions from each shot point. A reflection at approximately 1.8 seconds on the records was correlated over the area and the results are shown by the contours of Fig. 3. An anomalous area is

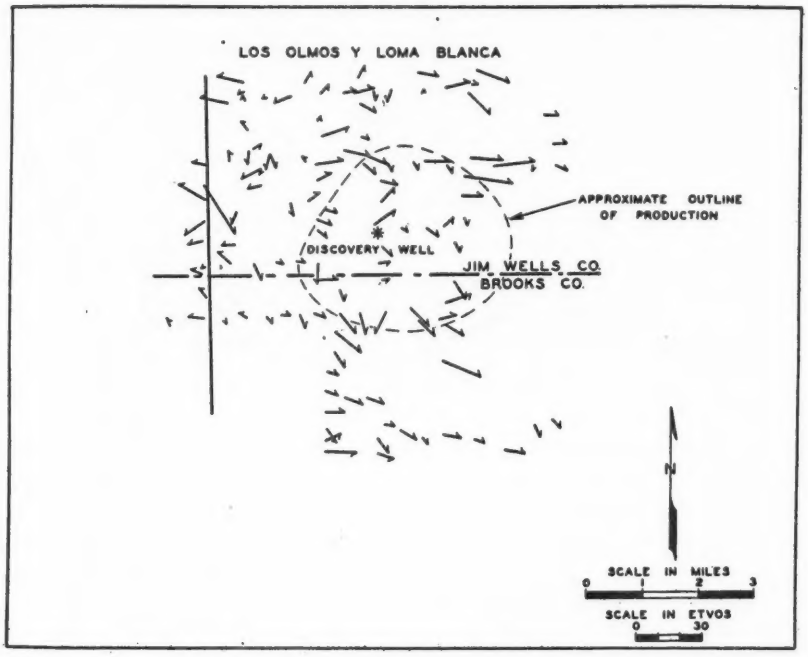

FIG. 2. Torsion Balance Gradients for the La Gloria Field. Survey made by Magnolia Petroleum Co. Crew, 1934–1935.

shown with two possible faults noted to adjust for misclosure in traverses. The structural delineation as shown in the figure conforms reasonably well with the approximate outline of production.

3. Two years later, in 1938, Magnolia reflection Party No. 4 with S. H. Stuart, party chief and John A. Lester, computer, shot with continuous profiling in the central part of the area; and with a 500 foot to 1900 foot surface coverage dip spread outside this central protion. The shot points are shown by small circles (Fig. 4) and were spaced approximately 1400 feet to 1900 feet apart. The dips indicated

by the reflections on the records were plotted on cross sections, a phantom horizon drawn on each section and the various traverses closed. The results of this work are shown by the contours of Fig. 4. This map shows 250 feet or more of closure. A northeast-southwest trending fault which is located in the low area in the western portion of the figure has been found from wells drilled subsequent to the geo-

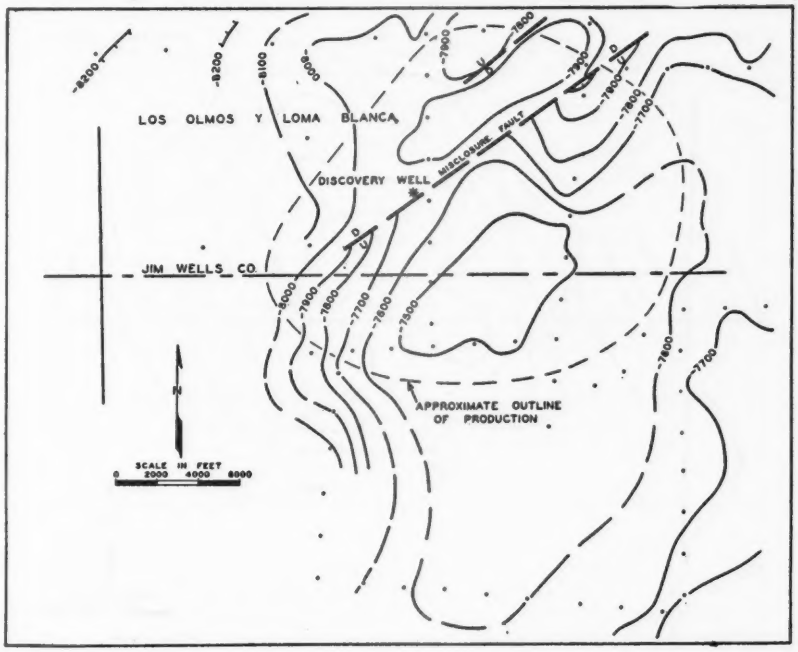

FIG. 3. Correlation Reflection Seismograph Map on −7500 foot horizon by Independent Exploration Co. Crew, 1936. Contour interval 100 feet. Shot points are shown by small circles.

physical work. Note the location of cross sections *A–A′*, *B–B′* and *C–C′* for the next three figures show reflection profiles in that order. Cross section *A–A′*, Fig. 5, is an east-west section at the western edge of the contour map. The phantom horizon is shown as a dashed line on each section. The absence of data below −8000 feet in the left central portion of this section is probably the seismic indication of the faulting previously mentioned. Cross section *B–B′*, Fig. 6, is also an east-west section but offset 3000 feet north of *A–A′* and continues

across the apex of the structure and down its eastern flank. Cross section *C–C'*, Fig. 7, is a north-south section across the apex of the structure.

4. As a result of the map shown by the dip data, it was later decided to do correlation shooting on the closed structure for comparison with the phantom horizon dip map. This correlation shooting was

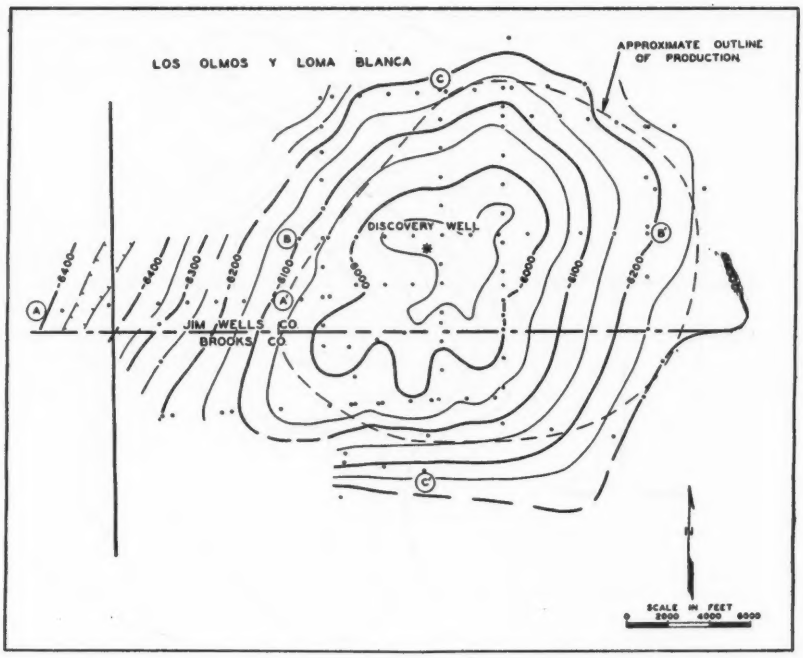

FIG. 4. Dip Reflection Seismograph Map on −5950 foot phantom horizon by Magnolia Petroleum Co. Crew, 1938. Contour interval 50 feet. Shot points are shown by small circles.

done by the same Magnolia crew using a reversed surface spread of 275 feet to 650 feet with two geophones per trace and a tie trace at each succeeding shot point. Shot points are shown by small circles (Fig. 8) and were spaced approximately 1000 feet apart. The results of this shooting, as interpreted by Paul E. Nash, who was then supervisor of seismic operations, are shown by the contours of Fig. 8. The correlation reflection events arrived from 1.53 to 1.61 seconds on the records. The results of both the dip and correlation surveys were es-

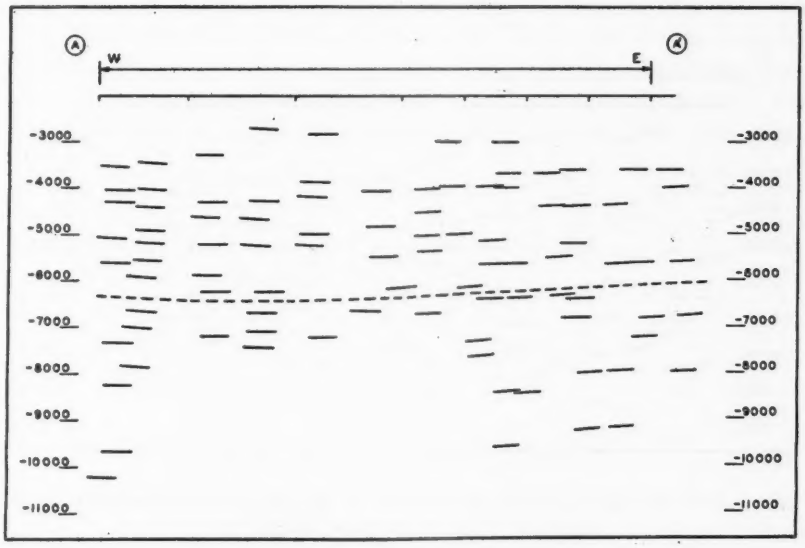

FIG. 5. Reflection Seismic Dip Cross Section *A–A'* by Magnolia Petroleum Co., 1938. Phantom horizon is shown by dashed line.

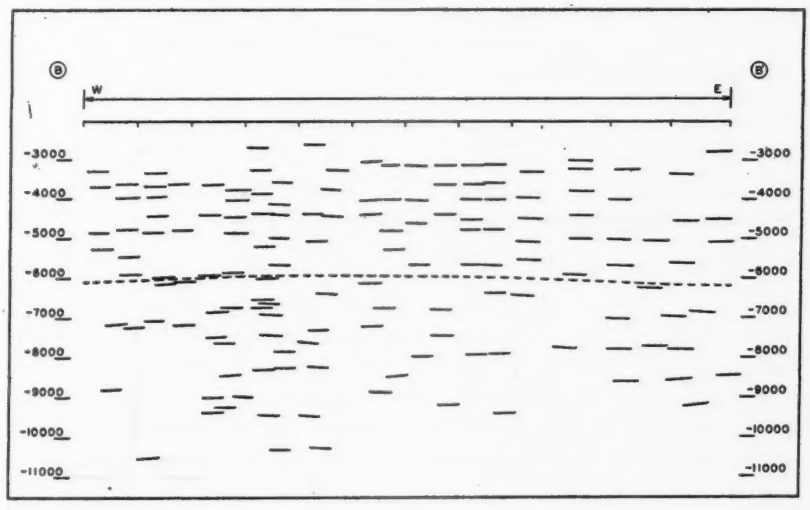

FIG. 6. Reflection Seismic Dip Cross Section *B–B'* by Magnolia Petroleum Co., 1938. Phantom horizon is shown by dashed line.

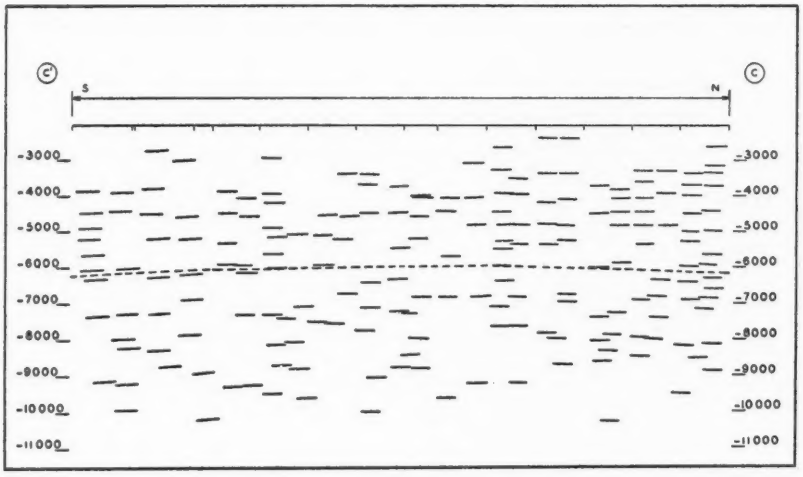

FIG. 7. Reflection Seismic Dip Cross Section *C–C'* by Magnolia Petroleum Co., 1938. Phantom horizon is shown by dashed line.

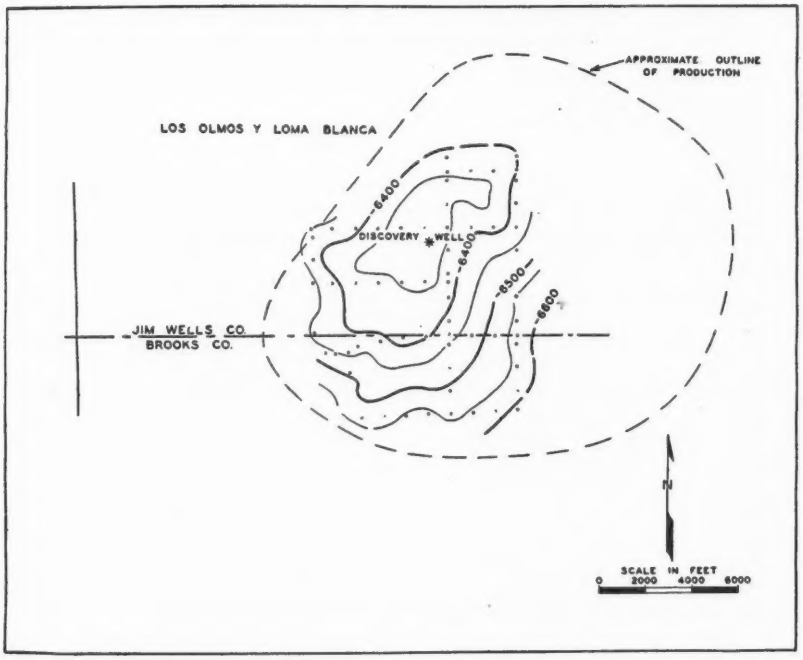

FIG. 8. Correlation Reflection Seismograph Map on −6350 foot horizon by Paul E. Nash, 1938. Contour interval 50 feet. Shot points are shown by small circles.

sentially the same, and it was from these maps that the location of the discovery well, Magnolia No. 1 Sam Maun was made. This well was started on November 16, 1938 and after drilling to a total depth of 7560 feet was completed on March 20, 1939 for an initial production of 165 barrels of 65 gravity distillate and 5,646,000 cubic feet of gas

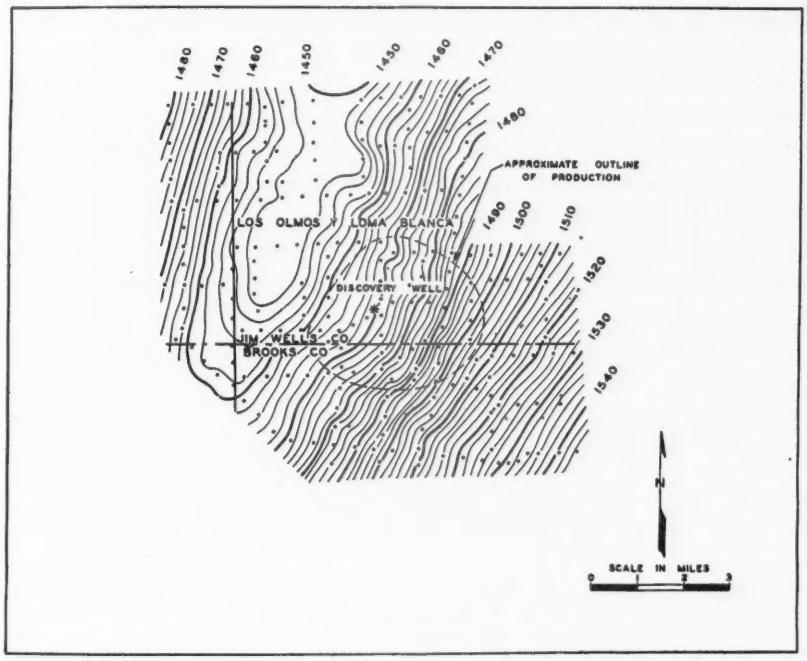

FIG. 9. Gravity Meter Contour Map by Coastal Oil Finding Co. Crew, 1943–1944. Contour interval 2 gravity units (0.2 mg.). Station locations are shown by small circles.

daily on a 5/16″ choke through perforations from 6560 feet to 6570 feet.

5. The gravity meter survey by a Coastal Oil Finding Co. crew under Lester Stoker, party chief was not run until 1943–1944. This survey was a part of a regional survey of the area. The gravity stations are shown (Fig. 9) as small circles 2000 feet to 3000 feet apart. Maximum allowable traverse misclosures in the vertical and horizontal surveys were 1.5 feet and 250 feet respectively. A LaCoste-Romberg gravity meter having a sensitivity of 0.8 gravity units per scale division was used. The gravity meter was read to the nearest 0.1 scale division and the gravity calculations were carried to the nearest 0.1 gravity unit. The gravity unit is equivalent to 0.1 milligal. Lati-

tude, free air and Bouguer corrections were applied to the observed values. In Fig. 9, the gravity values are contoured at an interval of 2 gravity units (0.2 mg). The results show a northeast-southwest minimum axis extending along the west side of the area with two maxima extending into the minimum axis on its eastern edge at the north and south, and the anomalous area is shown by the change in gradient of gravity in the south central portion of the figure.

In order to further evaluate the gravity data, the regional gravity influence was determined and eliminated from the observations. The resulting local anomaly, also contoured at 2 gravity unit intervals, is shown in Fig. 10. This treatment accentuates the recognition and location of the minimum anomaly and it is seen to coincide with the position of the producing area.

Fig. 11 shows a structural contour map on the base of a sand horizon at −5650 feet, prepared by the Magnolia Geological Department.

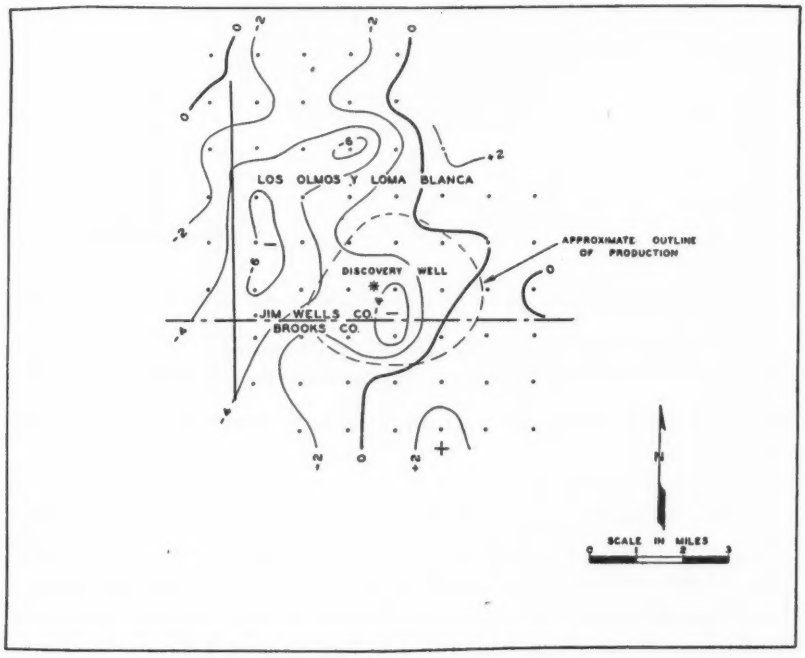

FIG. 10. Residual Gravity Map by Magnolia Petroleum Co.—Coastal Oil Finding Co. data. Contour interval 2 gravity units (0.2 mg.). Station locations are shown by small circles.

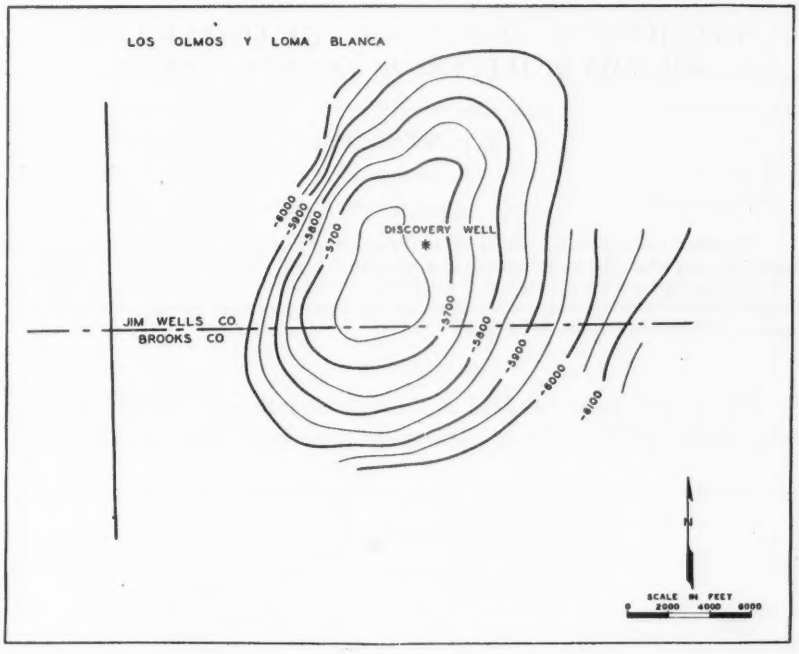

FIG. 11. Structural Contour Map on −5650 foot horizon by Magnolia Petroleum Co. Geological Dept., 1946. Contour interval 50 feet.

Production in the La Gloria Field is being obtained from sands in the Frio formation of Oligocene age. There are sixteen sands producing gas distillate from wells on the higher part of the structure while several flank wells produce oil. The field has been unitized and a cycling plant is engaged in processing the gas distillate.

At the end of 1945 there were 10 producing wells in the field and the cumulative production to January 1, 1946 was 298,299 barrels of oil and 9,867,071 barrels of condensate.

ACKNOWLEDGMENTS

The writer wishes to thank Magnolia Petroleum Company for permission to publish the paper; Mr. Henry C. Cortes for his help and suggestions in the preparation of the paper; and Miss Margaret Ekas and Miss Opal Allison together with other members of the Magnolia Geophysical Department for their assistance in the preparation of the material for the figures.

GEOPHYSICAL HISTORY OF THE LOVELL LAKE OIL FIELD, JEFFERSON COUNTY, TEXAS*

A. P. WENDLER†

ABSTRACT

The geophysical activity which led to the discovery of the Lovell Lake oil field was begun in 1929 when it was delineated as a minimum by the torsion balance. Two reflection seismograph surveys preceded the drilling of the discovery well, and a further detailed reflection seismograph survey after the discovery was made to outline the dimensions of the structure more definitively.

The Lovell Lake oil field is located in Jefferson County, Texas, some eight miles south of Beaumont and four miles southwest of

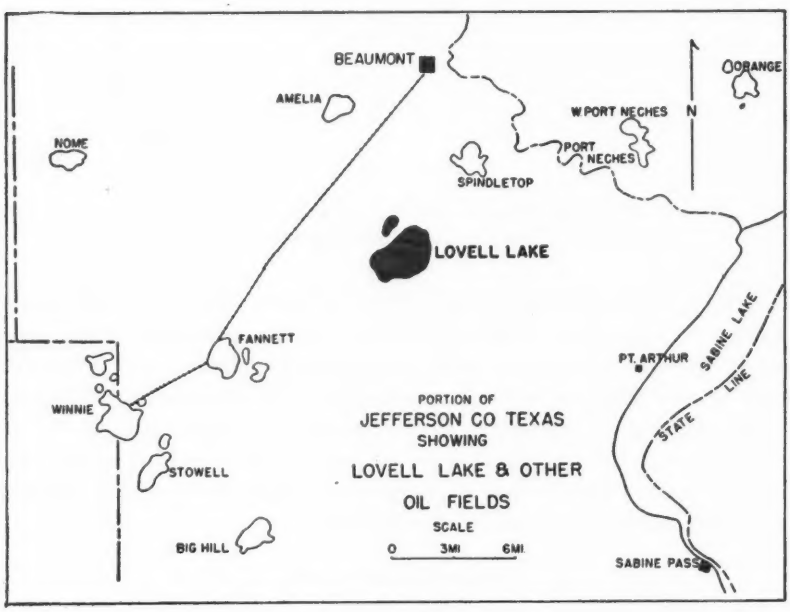

FIG. 1

FIG. 1. Map showing the location of the Lovell Lake oil field, Jefferson, County, Texas.

* Read at the Chicago and Houston Meetings of the Society, April, 1946.

† Humble Oil and Refining Company, Houston, Texas

Spindletop. The location of this field with respect to the surrounding territory is shown in Fig. 1.

The discovery well in this field was drilled by Glenn H. McCarthy, Inc. early in 1938 on a 20-acre "farmout" from a block of leases held by the Humble Oil and Refining Co.

As indicated in Fig. 2, the present productive area of the field consists of two lobes separated by a non-productive strip adjacent to

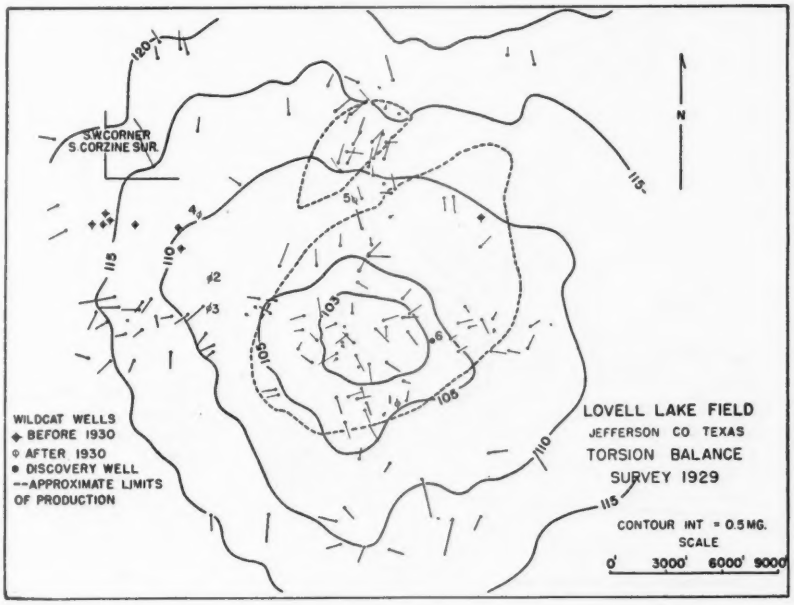

FIG.2

FIG. 2. Map showing the torsion-balance anomaly in the Lovell Lake area made by Cockburn, Gulf and Humble in 1929.

the hanging wall of a normal fault, downthrown to the southeast. The northwestern lobe is appreciably smaller than the other lobe which forms the major portion of the field. This portion of the field is called North Lovell Lake.

The main part of the field has produced some 10,000,000 barrels of oil of 36–38 gravity to date. At present the daily production averages about 4,500 barrels from two producing zones (7700′ and 7800′) and from about 100 producing wells.

The early history of the area was quite typical of many similar areas in this part of the Texas Gulf Coast. The somewhat irregular topography, the proximity to the prolific Spindletop field and the not unusual rumors of gas seeps served to excite some interest. Paul Weaver, of the Gulf Oil Corp., maintains that the only gas seepages in this area came from the graves of cattle which had died of a hoof and mouth disease in the Beaumont area during the twenties.

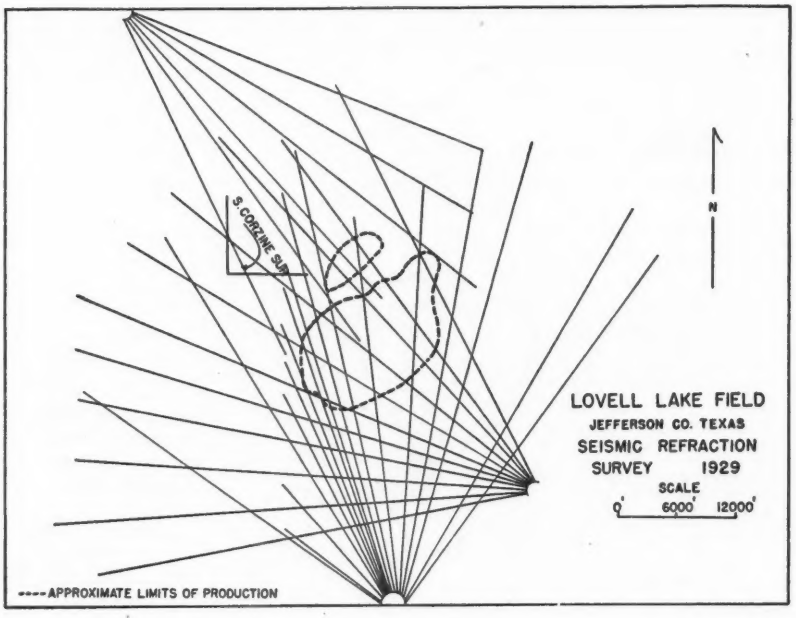

FIG. 3. Refraction fan survey made by Humble in 1929. No "salt dome leads" were detected.

Before 1929, as far as geological evidence was concerned, the area was not considered a favorable prospect. Nonetheless some eight dry holes had been drilled in the neighborhood up to that time.

The earliest geophysical activities in the area consisted of detailed torsion balance surveys conducted in 1929 by the Cockburn Oil Co., Gulf Oil Corp. and the Humble Oil and Refining Co. As shown in Fig. 2, a gravity minimum, with a closure of 1.2 mgl., practically concentric with the larger lobe of the producing area, was obtained. A gravity minimum of this type and magnitude is typical of many deep-seated salt domes in the Gulf Coast.

At the same time Humble covered the area by three refraction fans, as shown in Fig. 3. The results here were entirely negative since no "salt dome leads" were detected.

It was recognized that the gravity minimum was strong enough evidence to justify obtaining a block of acreage for exploratory drilling. The negative evidence of the "fans" could be explained in nu-

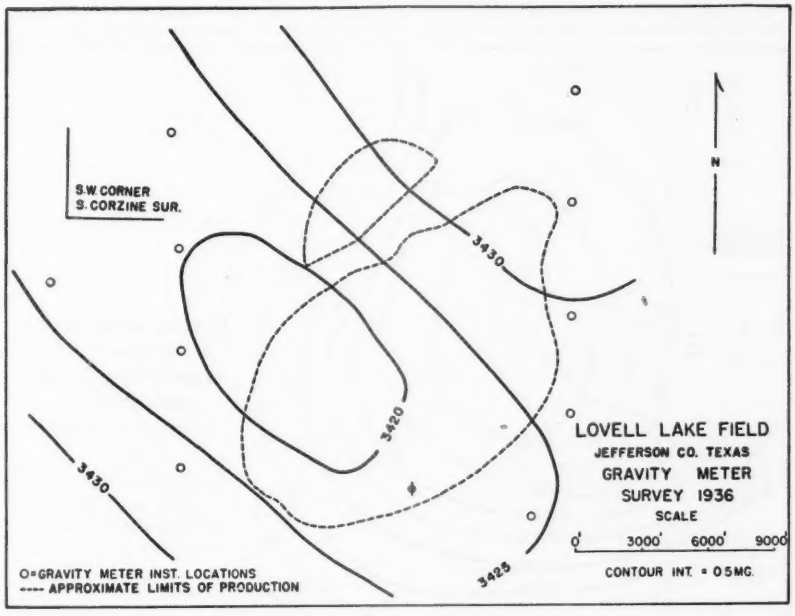

FIG. 4

FIG. 4. Map showing a gravity meter minimum in the Lovell Lake area.

merous ways: unfavorable fan layouts, very deep-seated salt core, etc.

Sometime later, in a regional gravity meter survey, the area was covered in less-detailed fashion, as shown by the location of the stations in Fig. 4. With this sparse control, a closure of 1 mgl. is indicated, though it is somewhat displaced from the corresponding torsion balance closure.

Quite definitely, in the light of present day knowledge, the gravity method located the Lovell Lake structure.

Humble and Gulf drilled their No. 1 Nelson to a total depth of 6,537 feet late in 1931. This well was located in the southern part of the larger lobe of the present producing area (shown as No. 1, Fig. 5).

Because of many mechanical difficulties, no oil or gas shows and no structural leads, the well was abandoned (about 1,100 feet above the producing zones) and most of the acreage was released. However, Humble did retain a few sizeable tracts.

The first reflection seismograph survey of the area by Humble was made in 1933. Twelve "dip-profiles" were shot across the gravity minimum. The interpretation of these results was based on both dips

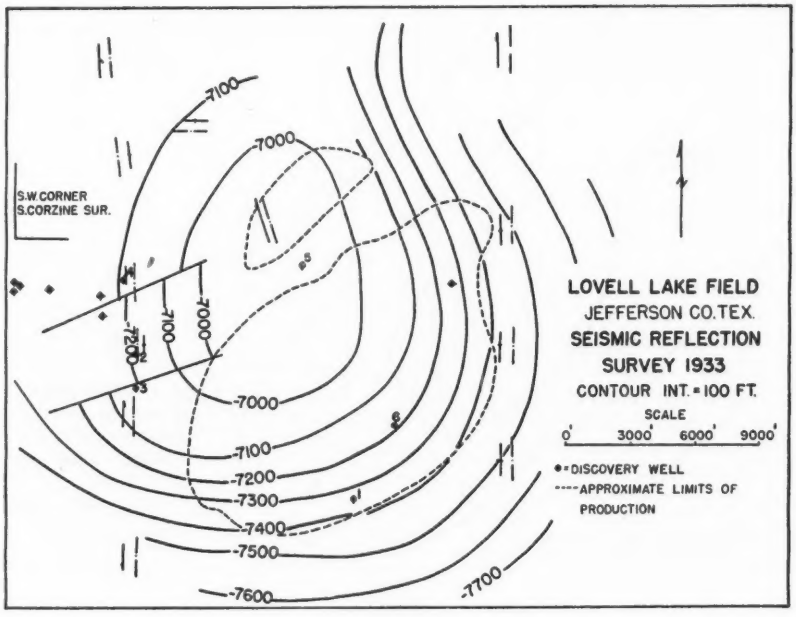

FIG. 5. Plat showing the results of the first reflection seismograph survey made in 1933.

and correlations and is shown in Fig. 5. The closing contours include almost all of the smaller lobe of the producing area but only a small part of the larger lobe, as we know it at present. The mapping of the small graben in the western part of the area was considerably influenced by the fact that information from some wells (indicated as Nos. 2 and 3 Fig. 5) was available.

The same area was reshot in more detailed fashion in 1935. Two separate interpretations of these data were submitted. The less-

favored interpretation is shown in Fig. 6. As indicated, this map shows a dome-like structure faulted on the northwest. The throw of the fault is some 700 feet down to the southeast. Both dips and correlations of the reflection records were used in constructing this map.

On the other hand, with the use of correlations only, the map shown in Fig. 7 was constructed and was considered the more plausible interpretation. One must remember that in those days, structural

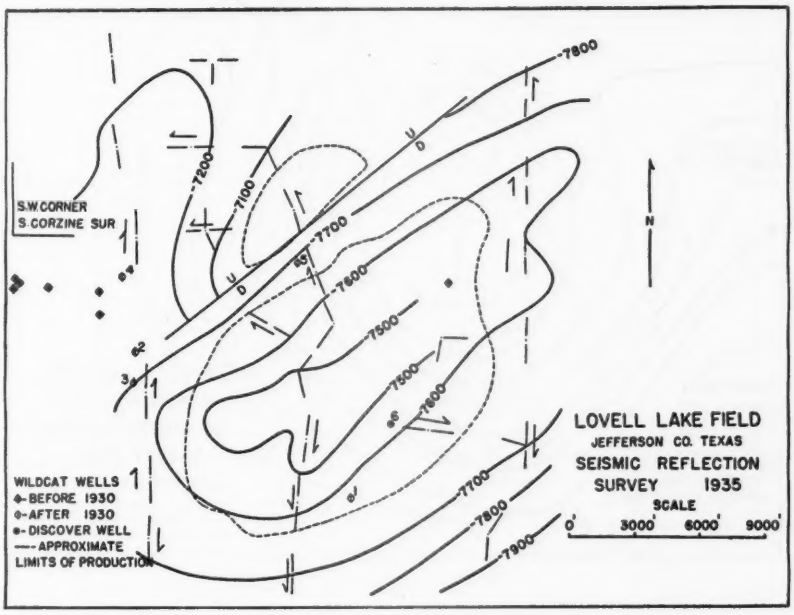

FIG. 6. The first and less-favored interpretation of the Lovell Lake structure made from a reflection seismograph survey in 1935.

features in the Gulf Coast, especially salt domes, were considered to be quite round.

In retrospect, it may be noted that the less-favored interpretation of Fig. 6, comes remarkably closer than either of the other two (Figs. 5 and 7), to representing the subsurface situation as it is known at present.

In 1934, surface geologists outlined a circular inlier of Lissie sands, centering on the north productive lobe, the highest part of the Lovell Lake anomaly. This inlier was considered tectonic in origin and was

described as the surface expression of the Cheek dome.* In 1936, a rather pronounced northwest-southeast structural nose, based on a sand and gravel bed about 200 feet below the surface was mapped by the core drill. The plunging axis of this nose crosses both producing lobes of the field. The samples of the Nelson well, drilled in 1931, were

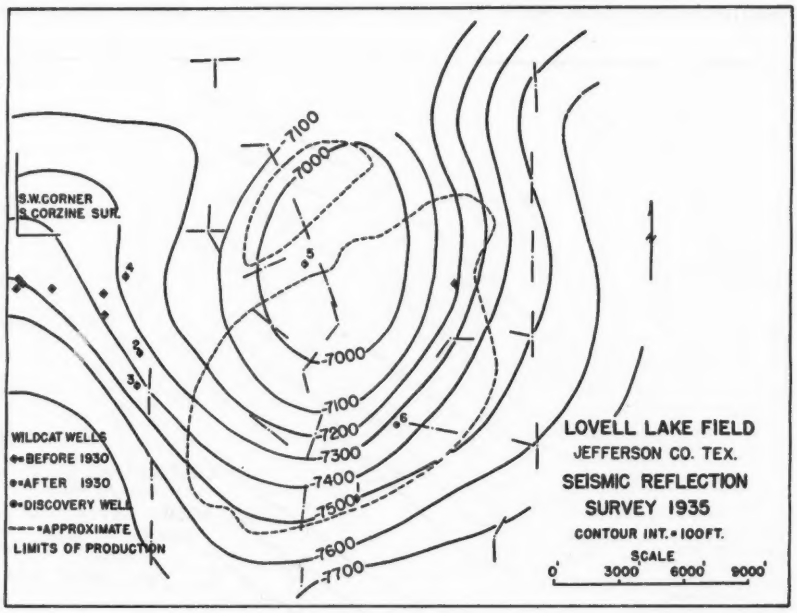

FIG.7

FIG. 7. The second and the more-favored interpretation of the Lovell Lake structure made from the reflection survey of 1935. The interpretations of both figures 6 and 7 were made from the same shooting data.

reworked for a more detailed analysis of faunal assemblages. A Discorbis fauna was found to be regionally high. Coupled with the results of the two reflection seismograph and the gravity surveys, these geological considerations revived interest in the area.

As a result, Humble in 1937, drilled its Jefferson Land Co. No. 1 (shown as No. 5 in Fig. 7). The location was made in the center of the 7,000-foot contour of the dome-like anomaly mapped in 1935 (Fig. 7). The well was drilled to a total depth of 8,458 ft., encountering ab-

* Later, when production had been established, the name Cheek dome was changed to Lovell Lake.

normally high bottom hole pressures—the first encouraging sign in this area. A geologic study of the lower section and a reworking of the seismograph data led to the conclusion that a large fault had been crossed.

A small part of the acreage held by Humble was farmed out to McCarthy, who drilled the Broussard Trust No. 1 discovery well early

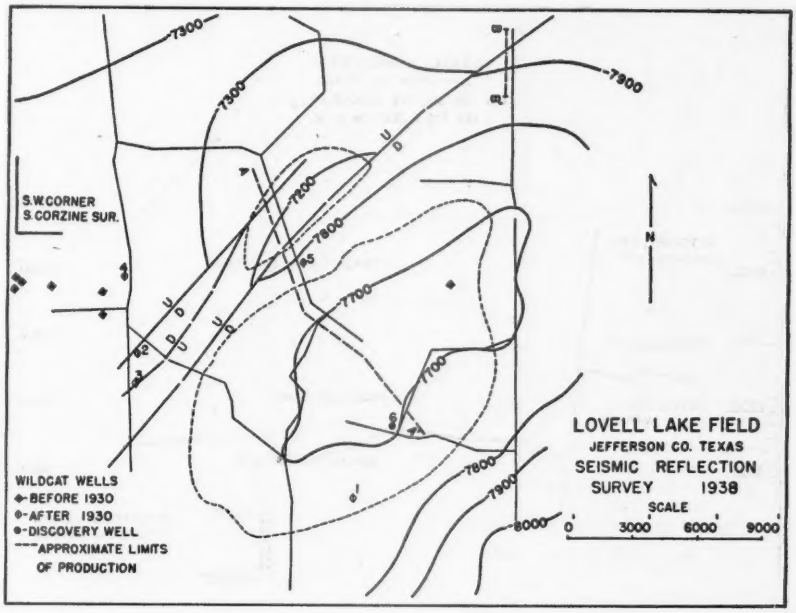

FIG. 8

FIG. 8. A detailed reflection seismograph map of the Lovell Lake structure made immediately after the discovery of the field.

in 1938. Immediately after the discovery of the field, Humble, using continuous profiling, made a further and more detailed reflection survey. The purpose of this survey was to define the Lovell Lake anomaly as closely as possible. The outstanding reflection observed in the previous surveys persisted over most of the area and served to yield the final seismograph picture as shown in Fig. 8.

A 700 foot fault, downthrown to the southeast, divides the structure into two distinct lobes. The lobe on the low side of the fault has a broad unbroken elliptical configuration, 5 miles by $2\frac{1}{2}$ miles, with the major axis in a northeast-southwest direction. The amount of closure is about 200 feet. On the high side of the fault, a semi-elliptical closure

of some 100 feet against the fault, 2 miles long and 1½ miles wide, is indicated. Several minor faults, parallel to the major fault, were mapped on the west side of the structure. The total area within the closures of the seismograph contours on both lobes is about twice that of the present producing area.

A detailed cross-section of the Lovell Lake field showing the

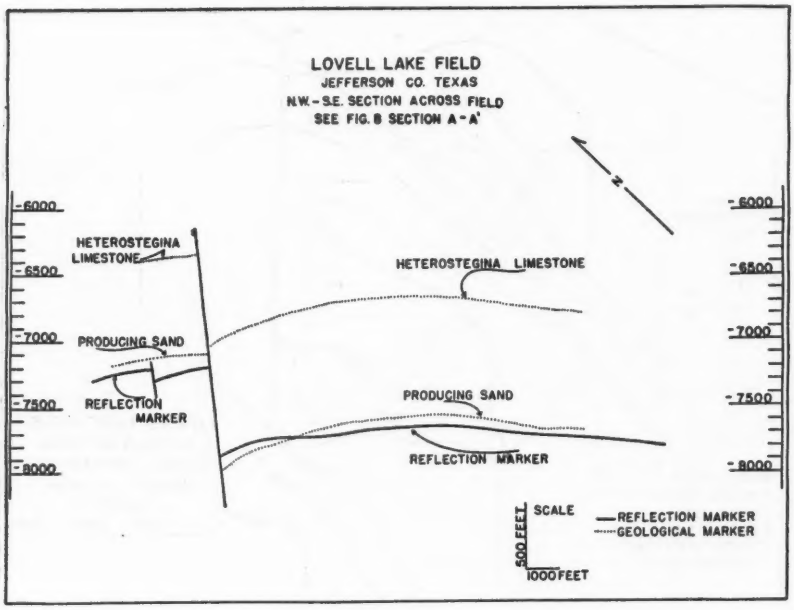

FIG. 9

FIG. 9. A detailed cross-section of the Lovell Lake structure comparing two geological markers with the reflection marker in this area.

producing zone and the top of the Heterostegina limestone is shown in Fig. 9. The solid line represents the reflection marker. This marker follows the trace of the producing sand very closely except near the hanging wall of the fault. Here the reflection trace crosses that of the producing sand. The positions of the seismic fault and of the geological fault are practically coincident.

The seismograph records from three adjacent spreads across the fault are shown in Fig. 10. The indicated offset in time which led to the interpretation of the fault is .120 second, corresponding to about 700 feet of throw. The separation of the detectors on the surface was 250 feet, so that each record corresponds to 1,000 feet of surface cover-

age on each side of the shot point, with the customary overlapping of profiles; that is, the shot points are 1,000 feet apart. The records shown are from the most northeasterly crossing of the fault. Not all the records across the fault on the other profiles are as clear-cut, but are definitive enough for the interpretation.

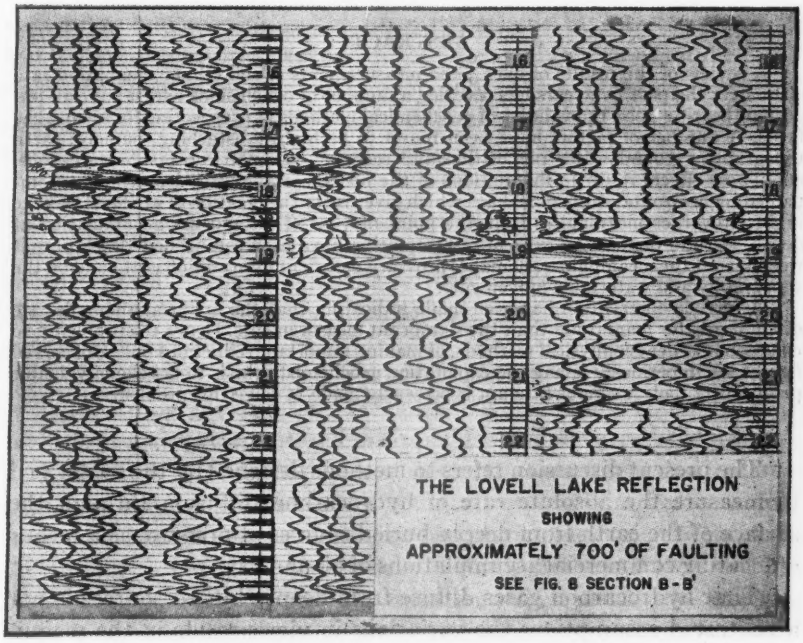

FIG. 10. Three seismograph records from three adjacent "straddle-spreads" across the Lovell Lake fault.

Thus, the effort in proving the Lovell Lake area to be an oil field was spread over 9 years. Following the mapping of the area as a torsion balance minimum, six deep holes were drilled, the last of which was the discovery well. If there be a moral to all this history, it is perhaps that persistency sometimes yields results.

The writer is indebted to the Humble Oil and Refining Company for the permission to publish this paper; to Mr. D. P. Carlton and Dr. M. M. Slotnick for helpful advice and suggestions; to Mr. Paul Weaver and Mr. W. F. Henniger of the Gulf Production Company; to the many colleagues who worked and reworked this area; and, finally, to Mr. J. D. Johnston for preparing the illustrations.

DISTURBING FACTORS IN GEOCHEMICAL PROSPECTING*

SYLVAIN J. PIRSON†

ABSTRACT

A review of the results of over 3,000 measurements of soil ethane emanation rate made over the past five years has revealed a number of conclusions which have an important bearing upon the validity of geochemical methods of prospecting for oil and gas fields. A number of factors have been found to be highly disturbing, namely: earth topography, ground water percolation and seepage, barometric pressure variations, etc. These effects result in fluctuations of the rate of escape of hydrocarbons accompanied by horizontal shifts of leakage which give rise to the creation of artificial leakage highs altogether meaningless from the point of view of oil and gas accumulation at depth. Certain qualitative rules of interpretation have been established which permit weeding out the meaningless anomalies provided sufficient information is at hand on the topography and watertable movement.

A further observation has been made indicating that the artificial anomalies are often of greater magnitude than the significant measurements. Hence the problems, so common in other geophysical methods, of making important reductions on the observed figures are imperiously facing the exploration geochemist if he is to develop a valuable prospecting tool. A serious attempt is presently made to solve this problem.

The present discussion refers to methods designed by the writer (1)[1] to measure the absolute rate of hydrocarbon diffusion through the surface of the earth from deeply buried sources of pressure as a means of locating commercial accumulations of oil and gas.

That hydrocarbon gases diffuse from deeply buried sources is not a contested assumption; the variations in views reside in the magnitude of the rate of escape, its uniformity, its pattern distribution and its spatial relationship to the source.

The method which has been in general use by the writer consists in making two sets of measurements, one in the field and the other in the laboratory. In the field the escaping hydrocarbons are aseptically and quantitatively adsorbed by sorbants which retain a sufficient sorption capacity in an atmosphere saturated with water vapor. A measuring station consists of several repeated measurements in neighboring shallow bore holes (2 feet deep by 2 inches in diameter). The precision of the measurements at a station is fair, from a probable error of about $\pm 10\%$ in low leakage areas to as much as $\pm 100\%$ in high leakage

* Read at the Chicago Meeting of the Society, April 2, 1946.

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[1] See References at end of paper.

areas. It is doubtful that one should expect a better precision in view of the erratic behavior of gases near the surface of the earth. Possibly, a better precision could be obtained by making measurements at a greater depth where soil conditions are more uniform and where channeling is not present to as high a degree as in the top soil.

The laboratory measurements consist of desorbing the field sorption tubes and measuring the liberated ethane by low temperature fractionation according to a modified form of N. R. Campbell (2) microgas analysis method. Over one hundred individual surveys were so carried out though many were groups of stations of not more than a few measurements which necessarily gave inconclusive results.

About thirty wildcat wells were drilled as a result of these surveys, which were made over widely variable geologic conditions, at first with a considerable degree of apparent success and later on with much less encouragement. With the passing of three years, an evaluation of the old results led to a number of empirical observations which may be summarized as follows:

1. Barometric pressure fluctuations disturb considerably the rate of hydrocarbon gas diffusion although it is possible to minimize and correct for such variations by the proper use of a repeated base station.

2. Areas of artificial high rate of gas escape are present over regions of ground water depression. This is tentatively explained as resulting from the release of gases collected by percolating meteoric waters from the drainage areas of the water table. If this hypothesis proves correct it should be possible to make quantitative reductions of the observations in such a manner as to leave only the significant anomalies, provided adequate data on rainfall, percolation, run-off, hydraulic gradient and permeability are known. Such a development is, however, only in its infancy.

3. Sharp topographic relief is instrumental in providing variations of path length to the diffusing gases with a shortening of path to stations located in valleys and a lengthening over hills, notwithstanding the drift superposed over this disturbance by ground water movement along the surface of the water table.

4. In regions of intense structural deformations, the bulk anisotropic permeability of stratified formations is influential in providing an updip drift in the gas diffusion patterns observed.

5. The presence of shallow gas horizons is always a troublesome occurrence. The elimination of this effect necessitates a large number of stations of high precision since the only way of distinguishing be-

tween a deep and a shallow source must of necessity be based upon the shape of the diffusion intensity curve, a deep source giving a broad anomaly while that of a shallow source is sharp. Generally, the maximum diffusion intensities in both cases will be of substantially equal intensity if the pressures within the sources are hydrostatic.

6. The possibility of the presence of a relatively uniform hydrocarbon diffusion field within sedimentary formations is strongly suggested by the observation of residual diffusion values in sedimentary areas where no oil and gas fields are known to exist.

The general conclusions here expressed may be illustrated by the

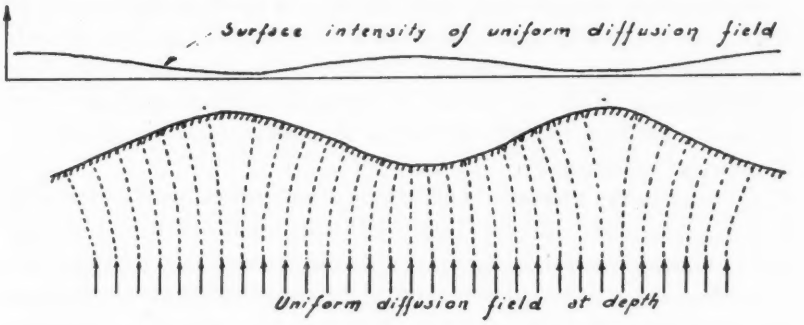

FIG. 1. Effect of topography on the observed intensity of a hydrocarbon diffusion field.

following figures and examples. Fig. 1 shows the distortion introduced by topography in a uniform diffusion field with the result that artificial anomalies are created. Fig. 2 illustrates several theoretical possibilities of obtaining artificial leakage highs depending on the relative movement of ground water with respect to surface drainage. The leakage patterns there represented by shaded areas are highly idealized and are predicated upon the assumption that the rate of diffusion of hydrocarbon gases in the water saturated horizons is much lower than the rate of horizontal percolation of the movable ground water. Hence, the liberation of hydrocarbon gases from water solution will appear more intense where the ground water movement will have slowed down to a rate comparable to gas diffusion in water. Obviously, the hydraulic gradient and the permeability of the water table will be the controlling factors of the diffusion patterns.

The influence of the water table may be illustrated by the examples

shown in Figs. 3 and 4. In Fig. 3, an area of effluent water seepage in Kansas, was surveyed by the gas diffusion or emanometric method. A high leakage trend parallel to the permanent streams was discovered and as the influence of ground water movement was unknown at the

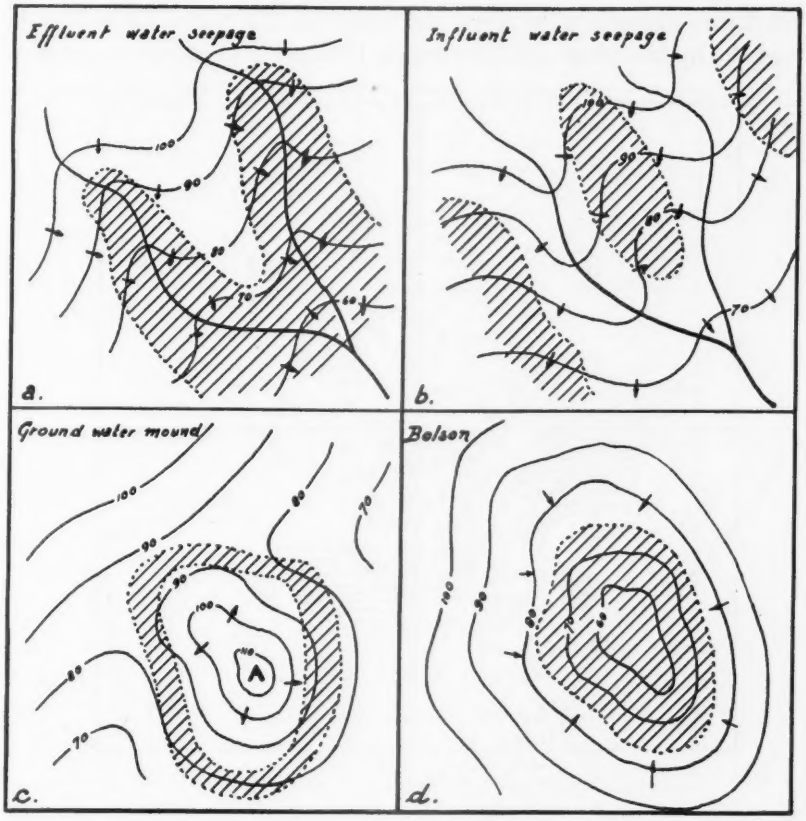

FIG. 2. Effect of water table movement on the observed intensity of a hydrocarbon diffusion field.

time, the drilling of a well was recommended at the location shown (eastern part Sec. 27) resulting in a dry hole at the Bartlesville horizon. It is now realized that the diffusion high resulted from a drift caused by the water table. Obviously the gases are liberated from solution where the hydraulic gradient becomes negligible which is in the thalweg (subsurface water stream), in this case somewhat offset from the main course of the stream.

Fig. 4 is another example taken from a neighboring region of Kansas but where the ground water movement is influent. Accordingly, the thalweg is located between the intermittent surface streams. The hypothetical location of the thalweg is indicated as inferred from the topography of the area. It may be noted that there is remarkable agreement between the trend of the water table trough and the hydrocarbon diffusion highs. Hence, the negative outcome of

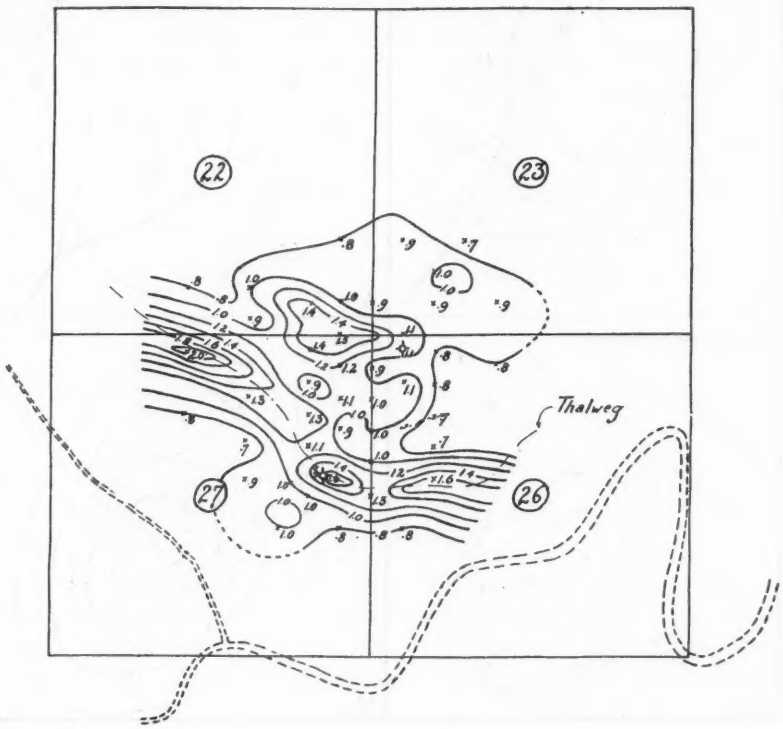

FIG. 3. Hydrocarbon emanation patterns associated with effluent seepage streams (dotted lines) in Kansas. (mm³ of ethane per square foot in 24 hours.)

the two tests drilled at the locations shown (I, in Southeastern Sec. 1 and II, in extreme southern part of Sec. 12) was to be expected.

Many other examples of a similar nature could be cited. In the majority of the cases the exploratory dry holes have been explained by their relation to the *water table trough* or to *sharp topographic features*. Although the present rules have an empirical character at this writing, they nevertheless indicate the necessity of seeking

quantitative methods of evaluation of the disturbing influences. A geochemical survey made without at least some means of taking these effects qualitatively if not quantitatively into consideration may be likened to a gravimetric survey without elevation correction or to a seismic survey without weathering correction. The desirability of

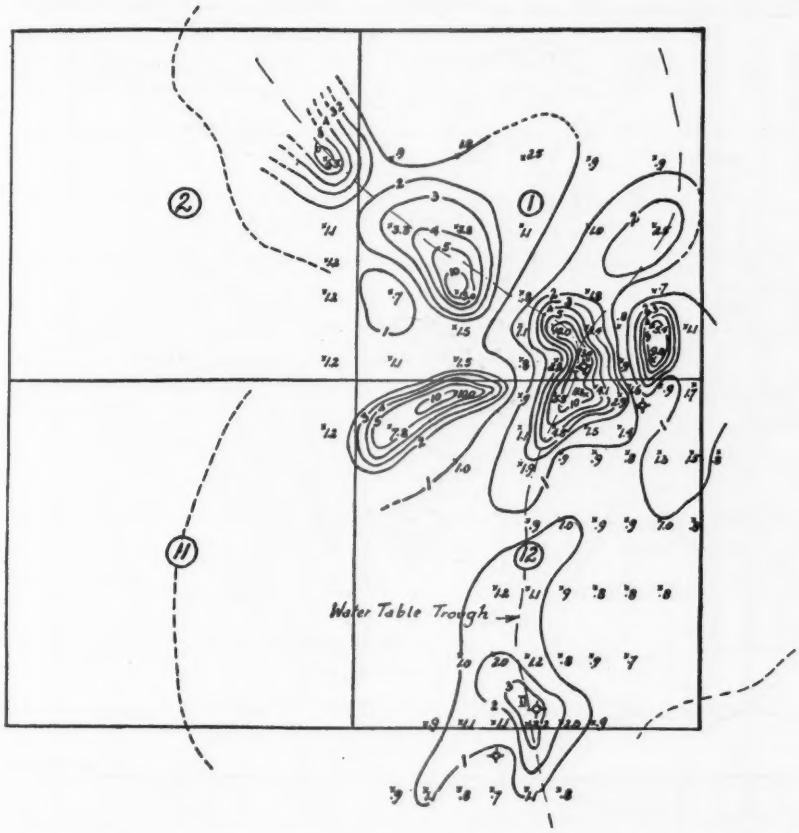

FIG. 4. Hydrocarbon emanation patterns associated with influent seepage streams (dotted lines) in Kansas. (mm³ of ethane per square foot in 24 hours.)

quantitative reductions of the observations will be immediately apparent when considering than an artificial high produced by either topography or ground water may be superimposed upon an actual leakage high from an accumulation of oil and gas under pressure. This may be illustrated by considering the map of the St. Jacob Field,

Madison County, Illinois (Fig. 5) which was surveyed while the field was in its early development stage. Outside of some other interesting features it may be observed that the diffusion high over the north dome would have been looked upon with suspicion since it is located

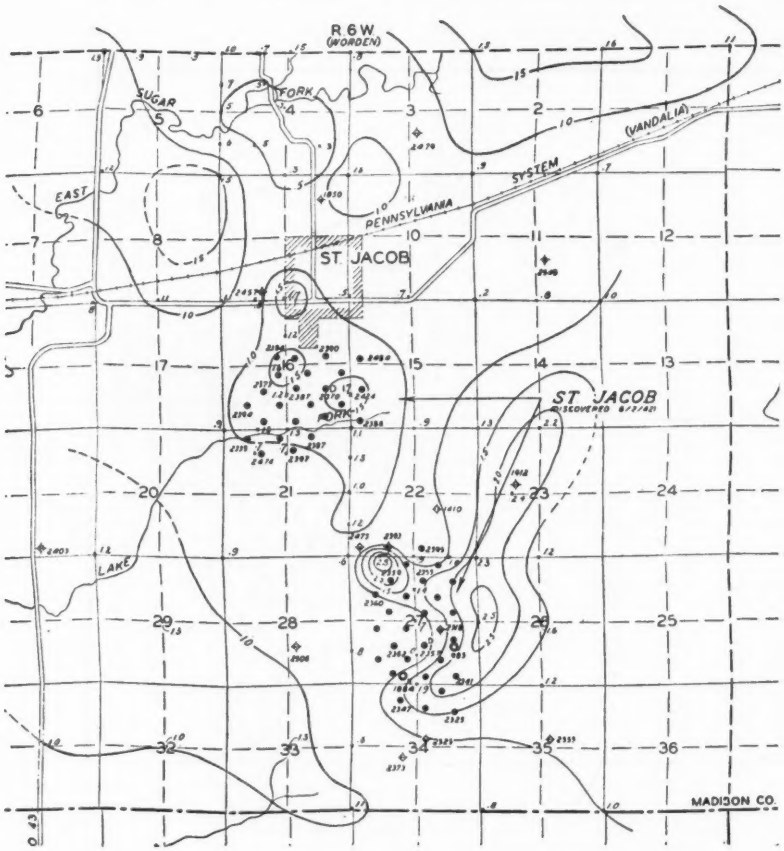

FIG. 5. Emanometric map of St. Jacob field, Madison County, Illinois. (mm³ of ethane per square foot in 24 hours.)

over the thalweg associated with a permanent stream, namely Lake Fork Creek.

In closing the review of the difficulties involved it might be added that the results of geochemical rate measurements are not all negative. It is, however, remarkable that the successes of the method have been

scored where the five sources of distorsion listed above were absent or of negligible effect. Fig. 6, which shows the results of surveys carried out in the early part of 1942 and superimposed over developments as of January 1, 1946, does not show, as yet, any failure. On February 19, 1942 the outcome of the Cameron Landwher #1 (NW NE Sec. 8, T. 5N., R. 7E. Clay Co., Ill.) was predicted as a pool opener whereas the western off-set wells were condemned. A later extension of the

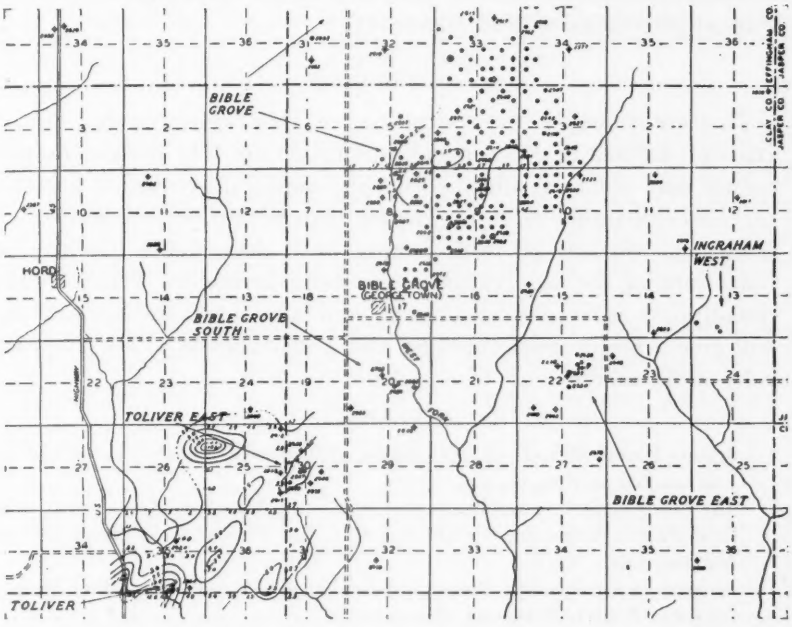

FIG. 6. Emanometric map of Bible Grove and Toliver fields, Clay County, Illinois. (mm^3 of ethane per square foot in 24 hours.)

survey dated March 25, 1942 predicted the eastern re-entrant of the Bible Grove Field in the NE of Sec. 9. Unfortunately, the geochemical survey was not sufficiently extensive to predict the full extent of the field, but whatever was predicted at the time has been verified by the drill at a later date.

The survey shown in S-W part of Fig. 6 was completed in April, 1942, with the prediction that the well in SW-NE Sec. 35, T. 5N., R. 6E. would be a dry hole. On the strength of the survey a well was drilled in SW-SW-SE, Sec. 35, T. 5N., R. 6E. which is the discovery of the one well pool (now abandoned) known as Toliver field. In 1943,

the development of the three well Toliver East field took place, which already at this date has paid out well for its development, by producing over 100,000 bbls. of oil. It is to be noted that this "pimple" pool is well outlined by the contour line of value 5 and that a number of dry holes have definitely established the limits of production to be substantially identical with this contour. An untested anomaly in the S.W. and the N.W. of Sec. 36 of a leakage intensity of the same order of magnitude as over Toliver East and on the same trend appears as another interesting wildcat possibility.

CONCLUSIONS

To state it simply, the conclusions of this cursory review of nine years of research in geochemical exploration are that the general procedure may not be condemned by philosophical agruments but that success comparable to, if not greater than with other methods of exploration, will not be forth-coming until dependable quantitative reductions of the observations have been developed. Perhaps these quantitative reductions need not be used in a routine manner but they will give a better understanding and a justification of the empirical rules outlined here.

REFERENCES

(1) Sylvain Pirson, Measure of Gas Leakage Applied to Oil Search. The Oil and Gas Journal, February 20, 1941, pp. 21–32.
The Geodynamic Process. The Producers Montly, May–June–July–August, 1941.
Geodynamic Prospecting for Oil and Gas. The Petroleum Engineer, Midyear Number, July 1, 1941.
Progress in Geodynamic Prospecting for Oil and Gas Fields. A.P.I. Meeting. April 17–18, 1941, Pittsburgh, Pennsylvania.
Recent Developments and Successes in Geodynamic Prospecting. The Oil Weekly. January 12, 1942, pp. 20–30.
Theoretical and Economic Significance of Geodynamic Prospecting. World Petroleum. April 1942. pp. 38–41.
Two Year Summary of Geodynamic Prospecting Results. The Oil Weekly. August 2, 1943. pp. 23–30.
Emanometric Oil and Gas Prospecting. The Petroleum Engineer. January 1946. pp. 132–142.

(2) N. R. Campbell, A Method for the Microanalysis of Gases by the Use of the Pirani Pressure Gage. Proc. Physical Soc. of London 33, 287 (1921).

THE AIRBORNE MAGNETOMETER

GARY MUFFLY*

ABSTRACT

This paper discusses the problem of magnetic exploration for oil from an aircraft. A new type of saturation magnetometer is described. Various orientation and stabilization schemes and their application to submarine detection and geophysical prospecting are discussed. It is shown that total-field measurement is far superior to vertical-component measurement. The newest Gulf apparatus using an automatically-stabilized continuously-recording total-field magnetometer is described.

Years before geophysical methods were applied to oil prospecting, the dip needle was important in locating iron ores and other magnetic minerals. The adaptation of this instrument to oil prospecting followed its development into a sensitive and stable device, the familiar Schmidt balance, which could chart deeper and less highly magnetized formations. The speed, economy, and simplicity of the magnetic method have encouraged its continuous use up to the present time. However, many geophysicists have forsaken it largely because of the difficulties which arise in interpreting the data in terms of geology.

ADVANTAGES OF AIRBORNE MAGNETOMETRY

In prospecting for oil, at least, the magnetic method is admittedly limited to reconnaissance work that should be followed up by other methods. When the measurements are made on the surface, the method is also subject to additional limitations which can be avoided by making measurements from the air. In some areas the readings of an ordinary magnetometer on the ground become almost meaningless because inhomogeneous magnetic material near the surface affects the instrument. Readings taken a few feet apart may vary so widely and irregularly that a useful contour map can not be drawn without taking an impractically large number of observations. The interfering mag-

* Development Engineer, Gulf Research & Development Company. The author wishes to give credit for the major part of the airborne magnetometer development to Victor V. Vacquier who, although not a collaborator in this article, developed the first magnetometer element suitable for airborne geophysical prospecting, and did a great deal of the pioneer work on the first types of orienting apparatus which demonstrated the possibilities of airborne magnetometers. Mr. Vacquier, a former employee of Gulf Research & Development Company, is now employed by the Sperry Gyroscope Company, Inc.

netic rocks may be within several feet or yards of an instrument operated on a tripod. A magnetometer flown in an airplane a few hundred feet above the surface avoids these effects because the many local highs and lows over an enlarged area tend to cancel one another in addition to being attenuated by the increased distance. This effect is of most pronounced value for eliminating very shallow disturbances, but the same principles can also be applied to minimization of the effects of magnetic sediments at medium depths in case they make difficult the analysis of the deeper magnetic basement rocks. Thus one can fly high when studying a deep basement or low when interested in shallower effects. Flights at several elevations over a given area give contours which qualitatively show the distribution of magnetic material with depth. The many small wrinkles on the low-elevation map gradually disappear with height. The curves become quite smooth when taken two or three miles above the surface. In addition to the advantages of making measurements at controllable elevation, flying an instrument makes continuous recording of profiles a practical possibility, and work is speeded up tremendously. Forbidding areas over water, jungle, desert, or arctic tundra can be explored almost as easily as favorable areas. Programs that would take weeks of surface work are now covered in hours of flying time.

FUNDAMENTAL REQUIREMENTS OF AIRCRAFT MAGNETOMETERS

The usual prospecting magnetometer is the familiar Schmidt balance. This instrument is available in various refined forms, all of which use magnetic needles balanced on suitable bearings. They usually measure the vertical component of the magnetic field by balancing the torque of a horizontal needle against gravitational force. The delicate balance of the needle requires a solid mechanical support for stability and leveling. Moreover the delicate bearings are too fragile to withstand shock. This rules out use in an airplane or any other moving conveyance. Consequently, the first step in developing an aircraft magnetometer was to produce a magnetometer element that would operate without using mechanical forces or movable parts that would be subject to gravitational or vehicular accelerations. These characteristics are inherent in certain magnetometers which make use of saturation effects in high-permeability magnetic material, and consequently are called saturation magnetometers.

Magnetometers of the saturation type were in existence many

years ago, but they apparently all fell short of the required sensitivity by a few orders of magnitude, exhibited troublesome hysteresis effects, or were mechanically or electrically impractical for airborne prospecting. This type of magnetometer is basically a rod or strip of ferromagnetic material acting as an open magnetic core for one or more a-c windings connected to exciting and indicating circuits which can measure the magnetization produced in the core by an ambient magnetic field. The core is ordinarily a simple straight rod or strip of high-permeability material such as permalloy. Such a core is magnetized by the component of field parallel to its length. This magnetization induced by the ambient field is ordinarily a steady quantity which will not create voltage output in the windings on the core, and it is therefore necessary to apply periodic current to one or more windings to create rapid changes of flux and consequent induced voltages of useable magnitude. These induced voltages depend on the nature of the applied magnetizing current as well as on the amount of magnetization created in the core by the ambient field. Various types of symmetrical or unsymmetrical exciting waves have been used, such as pulses, sine waves, and special wave shapes. The resulting induced voltages have been handled in different ways to detect changes of amplitude, phase, harmonic content, wave shape, or some combination of the effects that result from the changes of ambient field.

Some early saturation type magnetometers used two parallel magnetic cores. The cores in this type of magnetometer element are magnetized in the same sense by the ambient field, but the periodic excitation is directed oppositely in the two cores. Thus, at any particular instant in the excitation cycle, the magnetizing effect of the exciting current is added to the ambient field component in one core and subtracted from it in the other core. This results in a difference in the instantaneous fluxes in the two cores which increases in proportion to the value of ambient field, being zero only if the two cores are subjected to zero ambient field. Of course the cores and coils must be substantially identical to bring this condition about. The a-c output of such a two-core element can be taken from a single winding placed around both cores, or from separate windings, one on each core, connected in opposition. Such an arrangement balances out the exciting wave and makes it simpler to work with the changes caused by ambient fields. This variety of saturation magnetometer has been variously described as a flux gate or magnetic gate type magnetometer.

The magnetometer element invented by Vacquier at the Gulf Research Laboratory in 1940 was of the saturation type, but incorporated improvements which made it small and simple and raised its sensitivity above previous types of magnetometers so that a sensitivity of one gamma (10^{-5} oersted) could be readily provided with very little apparatus. This elevated saturation type magnetometers from devices of the laboratory or compass classes to instruments suitable for prospecting. The difference may be compared to that between a modern Schmidt balance and a crude dip needle.

The new magnetometer element itself, which will be treated in more detail later in this article, is only a partial solution to the problem of prospecting from the air if one is to realize the desirable accuracy of about one gamma. A simple computation will show that if the core of the magnetometer is turned vertically to measure the vertical component, a typical field value of 55,000 gammas at a 70° dip angle will require the element to remain truly vertical within about 11 seconds of angle for the one-gamma accuracy. However, an airplane may pitch and roll through several degrees per second, and the allowable angular motions of the magnetometer will be a few thousand times less than the normal angular motions of the airplane. A mechanism made to provide such stability in an airplane would be quite a feat of engineering. No such mechanism was attempted, however, because the vertical direction itself can not be determined in an airplane with sufficient accuracy to make such a mechanism useful. When an airplane turns, the centrifugal force adds vectorially at right angles to the gravitational force to create a false apparent vertical. In a normal turn, for example, a plane may easily bank 20 or 30 degrees and cause a corresponding error of the same value (for a perfect bank) in the apparent direction of gravity. Even in normally straight flight occasional curvature of the course can not be avoided, so that errors of perhaps a degree or so occur in the apparent direction of gravity. To keep the error of the vertical direction down to 11 seconds, the path of the plane would have to have a minimum turning radius of about 3,300 miles. Forward acceleration or deceleration would also have to be held to impossible limits for similar reasons. The 11-second allowable error in the apparent direction of gravity would be reached by an acceleration or deceleration of the plane so gradual that it would require over two hours for the speed to change by ten miles an hour. These considerations seem to rule out practical use of vertically oriented magnetometers (and, incidentally, gravimeters) in aircraft.

The aircraft magnetometer recently discussed in GEOPHYSICS[1] used vertical gravity orientation, contrary to the requirements of oil prospecting from the air. This was possible only because of the low sensitivity which they used, approximately 1,000 gammas compared to about one gamma for the present apparatus. Their instrument was a rotating induction coil with a commutator, oriented pendulously on gimbals.

In order to get away from orientation with respect to the gravitational field being rendered erratic through airplane accelerations, the concept of orienting with respect to the magnetic field was introduced. A very considerable simplification and advancement of technique is accomplished by orienting the magnetometer with respect to the terrestrial magnetic field itself. If a magnetometer is oriented with its axis of sensitivity parallel to the magnetic field instead of vertically, it measures the total value of the field. Any error of alignment with the field will then decrease the observed indication by a value proportional to the cosine of the angle of error. Thus small deviations will create very small errors. Although these errors increase approximately as the square of the angular error they are very small for small angles. Under these conditions the angular tolerance for a one-gamma error becomes about 23 minutes. This is more than 100 times the angular tolerance in the previous example of a vertically oriented magnetometer. Furthermore, the magnetic field itself can be used as the reference direction for the orienting mechanism. This eliminates the troubles due to the uncertainty of the gravitational vertical direction, and makes stabilization possible even during maneuvers.

The total-field orientation of the aircraft magnetometer changes the interpretater's thinking habits considerably. However, measurements and interpretation are no more fundamental if based on the vertical component than if based on any other component. Vertical measurements were probably chosen in the first place mainly because of the simplicity of using the gravitational vertical as a reference in setting up magnetic balances. With total-field orientation a large anomaly causes the instrument to be oriented in very slightly different directions over various parts of the anomaly just as in the case of gravity surveys. Since the anomalies are relatively larger in magnetic work, this effect is greater than in gravity work. Nevertheless the

[1] A. A. Logachev, "The Development and Application of Airborne Magnetometers in the U.S.S.R.," (Translated by H. E. Hawks) GEOPHYSICS Vol. XI, No. 2, April, 1946, pp. 135–147.

angles involved will be too slight to alter appreciably the resulting picture of the anomaly. Magnetic ore-body anomalies comparable in magnitude to the earth's field would of course be an exception to this.

HISTORY OF DEVELOPMENT

The airborne magnetometer has had an abnormal history of development due to conditions imposed by the war. As soon as the Vacquier element and its associated electrical circuits were developed, thought was given to military applications. The most obvious and urgent military use was the detection of submerged submarines, and the majority of the early work on this device at the Gulf Research Laboratory was concentrated on this problem. The submarine menace was so close at hand that the problem was to get useable results as soon as possible. The value of the device had to be proved quickly to skeptical authorities of the Armed Forces in order that unhampered support would be given to the development. As a result the first anti-submarine magnetometers were built for quick results rather than for engineering perfection.

By early 1941 several ways of stabilizing a magnetometer element in a moving airplane had been invented. The first thought was to use a vertical gyroscope to maintain the element vertical. This idea was dropped at an early date for reasons already referred to, and all subsequent ideas were based on parallel or total-field orientation. The next development was to retain the vertical gyroscope but to pre-set the element to the local dip angle and then manually turn the whole unit about a vertical axis to obtain maximum indication corresponding to total-field or parallel alignment while the pilot held the plane on a definite heading. An early flight test was made with the cooperation of the Sperry Gyroscope Company and Mr. Preston R. Bassett, now its president. It was planned to take another forward step, namely to replace the manual adjustment by a servo control actuated from a second magnetometer acting as a compass. This would relieve the pilot of the necessity of holding an accurate compass course, and would make the instrument orient itself automatically except for the manually pre-set dip angle adjustment. A successful anti-submarine magnetometer, known as the MAD (magnetic airborne detector) Mark I, was built on this principle. This model convinced the Navy of the practicability of the idea. As a result, Gulf's efforts were, by Navy directive, concentrated on producing more units of the somewhat improved Mark II version of the same instrument for immediate use. It

was realized that this model had certain limitations. The precision of the device was limited by the manual dip angle setting. It was subject to misorientation on maneuvers due to precession of the gyroscope brought about by the shifting direction of apparent vertical. Nevertheless the Navy was justified in ordering additional units of this type to fill the gap of immediate combat requirements. These units were readily developed because the requirements for servo compass control of direction were not severe and the gyroscope avoided need for servo control of the faster pitch and roll movements.

The other ideas on stabilization, which predated the successful demonstration of the Mark I-Mark II type of apparatus were better in principle. All were based on using the magnetic field itself without gravitational reference for bringing about the automatic alignment for total-field indication. One version due to Ralph D. Wyckoff of the Gulf Laboratory retained the gyroscope but used two auxiliary orienting magnetometers and an air-jet arrangement to supplant the gravity-controlled precession used on the usual vertical type of gyroscope. A model was built which showed the practicability of this scheme although there was no time to continue its development. Another scheme called for three mutually perpendicular magnetometers without a gyroscope: two for orientation by means of quick-acting servo motors and a third one to measure the field. This scheme was used later by other laboratories which developed the magnetometer into the various production models, of which several hundred were produced for anti-submarine work. A third scheme was to use a single magnetometer element for measuring the field and simultaneously detecting misorientation. This was accomplished by an arrangement wherein the magnetometer axis was shifted rapidly in various directions to sample the field so that the maximum value could be sought out by servo motors. There were important advantages of this scheme, but it had to wait until various urgent war problems were handled before time could be devoted to it. When the end of the war was well on its way it was therefore developed for Gulf's own geophysical use.

The contributions of other organizations to the problem of anti-submarine magnetometers are not to be overlooked. The success of the initial relatively crude models stirred up a tremendous amount of activity. Gulf's part of this subsequent activity was necessarily minor because of limited space and personnel due to other defense commitments. Development work was largely carried elsewhere while addi-

tional Mark II units were being constructed at the Gulf Laboratory for immediate use in the anti-submarine patrol. In June 1941, the National Defense Research Committee initiated an intensive magnetometer program through Columbia University which set up its Airborne Instruments Laboratory. Coordinated studies were located at the General Electric Company, Sperry Gyroscope Company, and possibly other places. Similar work was done at the Naval Ordnance Laboratory and in cooperation with them, at the Bell Telephone Laboratories. Both of these combinations of organizations produced successful instruments for submarine work. Some geophysical work has also been done by others by adaptation of the Navy equipment to the prospecting problem.

THE GULF PROSPECTING EQUIPMENT

A complete prospecting equipment comprises an airplane with usual flight equipment plus unusually elaborate position-recording devices and a continuously recording magnetometer. The aircraft is a twin-motored amphibian capable of carrying a crew of three men in addition to about 500 pounds of special apparatus. Flight equipment includes radios, barometric and radio type altimeters and a radio-compass. The special position-recording devices used depend on the nature of the area being surveyed and may include special cameras, an air odograph for mapping the course automatically from integrated air-speed data corrected for wind direction and velocity, and radio locating devices of the Radar, Shoran, or similar types. The magnetometer equipment comprises the measuring or detecting element itself, an oscillator to excite it, a vacuum tube circuit to amplify and detect the output variations of the element, orienting devices to keep the element aligned, a potentiometer circuit to compensate or buck out large changes of field, and a recorder for the magnetic variations encountered in the area. A "bird" or streamlined housing is provided so that the magnetometer head and servo motors can be towed at a distance from the plane to avoid magnetic effects due to d-c circuits in the plane, induced and permanent magnetism in magnetic parts of the plane, and eddy currents set up in the aluminum skin and other parts of the plane by motions relative to the earth's field.

The magnetometer element itself has been made in many different forms and has used many types of exciting and detecting arrangements. However, the forms that are highly sensitive and free of hysteresis of indication have in common cores of very high permeability

material such as permalloy or mu metal, a high ratio of core length to cross section, thin core material to avoid eddy current effects, a relatively high degree of saturation, and detecting circuits which are sensitive to effects brought about by phase shifts occurring in certain parts of the cycle.

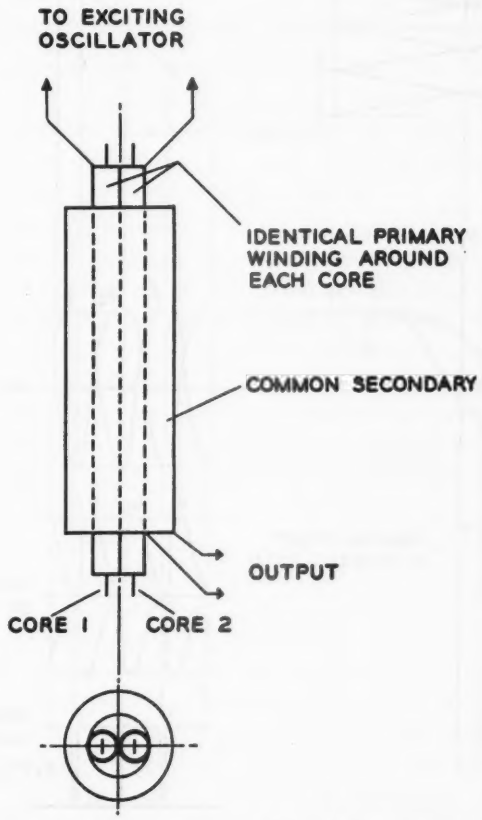

FIG. 1. Diagram showing arrangement of a typical saturation magnetometer element with oppositely excited primary windings on two separate cores, and a secondary common to both cores.

Fig. 1 shows a typical element, and Fig. 2 shows qualitatively how it may be operated. The excitation frequency may fall anywhere in the audio frequency range. 1,000 cycles is used in the present apparatus.

The output of the element of Figs. 1 and 2 may be amplified and

rectified to get a d-c proportional to the ambient field. Preferably the voltage pulses are handled so as to maintain their sharp peaks, as these peaks can operate peak type rectifiers, thereby maintaining the

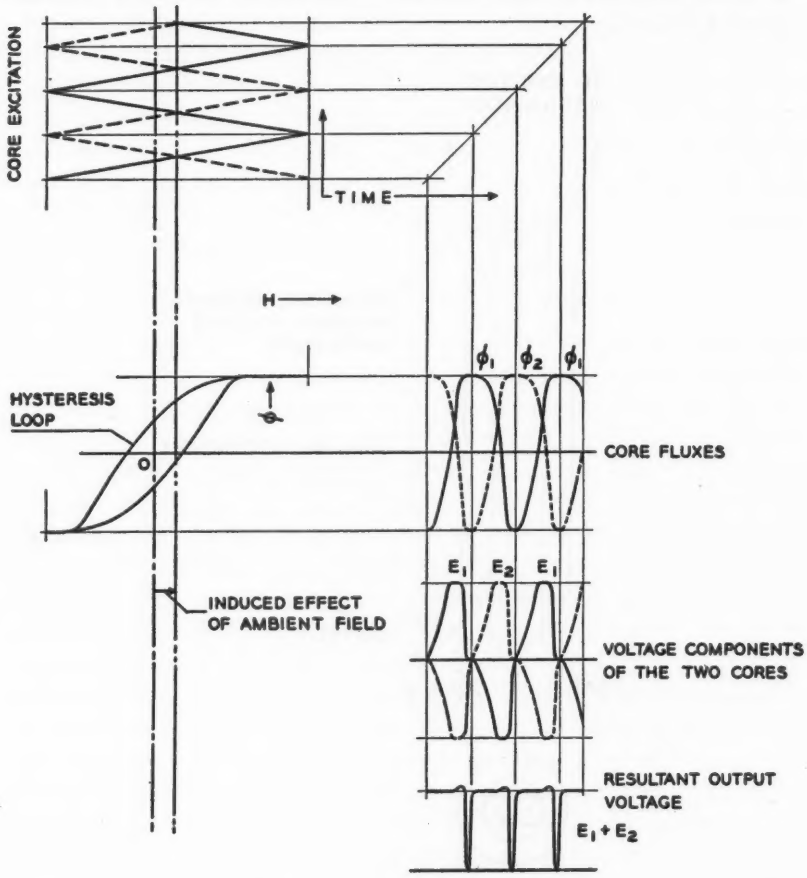

FIG. 2. Qualitative diagram showing operation of a saturation magnetometer. The two cores are excited in opposing phases. In the presence of an ambient field the resulting voltage components of the two cores are shifted slightly in phase. If steep wave patterns are used, this results in sharp pulses of high amplitude.

high voltage sensitivity inherent in the pulses. This type of operation gives a high voltage sensitivity because a very small change of field creates differential peak voltages approximating the maximum peak voltage output which either coil alone can produce, as Fig. 2 shows.

Where average type rectifiers or power-operated devices are used this advantage is lost. For instance, when the second harmonic output of the magnetometer coils is used by inserting a filter, much of the output, which is in the form of higher harmonics for the high degree of core saturation, is lost. It must be made up by means of amplification. Nevertheless, magnetometers based on second harmonic operation have been produced by others. The rectified d-c output voltage of the magnetometer circuit may vary by several hundred volts over a range of field values a few hundred or thousand gammas wide. A linear part of this range may be selected as the recording range of the complete apparatus, or the device may be used as a null indicator with the recorder indicating the field-nullifying current.

The complete Gulf magnetometer apparatus is shown diagrammatically in Fig. 3. The magnetometer element is mounted on gimbals. Rotation of the element about either gimbal axis is effected by one of the servo motors whenever misalignment occurs. Any misalignment is detected with the aid of the radial magnetic vane which is revolved continuously in a plane perpendicular to the cores and placed adjacent to one end of the cores. At any instant the vane has the effect of displacing the axis of sensitivity slightly in its own direction. The vane is revolved by a small non-magnetic centrifugally governed air turbine, which is supplied compressed air through the gimbal bearings. Thus the actual axis of sensitivity is whirled or nutated around the axis of the cores, making a constant angle of a few degrees with that axis. If the cores happen to be aligned with the field, the axis of instantaneous sensitivity makes a constant angle with respect to the field vector, and the detector circuit produces the same output at all points in the revolution of the vane. However, if there is a displacement or misalignment of the average axis, then the element will in effect vary its angle with respect to the field. At one point in the orbit of the vane the detector circuit will produce a maximum output, and at the opposite side of the orbit the output will be a minimum. In other words, the d-c detector output, which indicates the value of field in the direction of the average axis, will have a superimposed a-c modulation which will increase in amplitude with increasing misalignment, and the phase angle of the modulation will be indicative of the direction of the misalignment. It can be shown that the modulation is a pure sinusoidal wave which increases as the sine of the angle of misalignment, and that the d-c component or field indication still follows the cosine law with respect to displacements of the average axis.

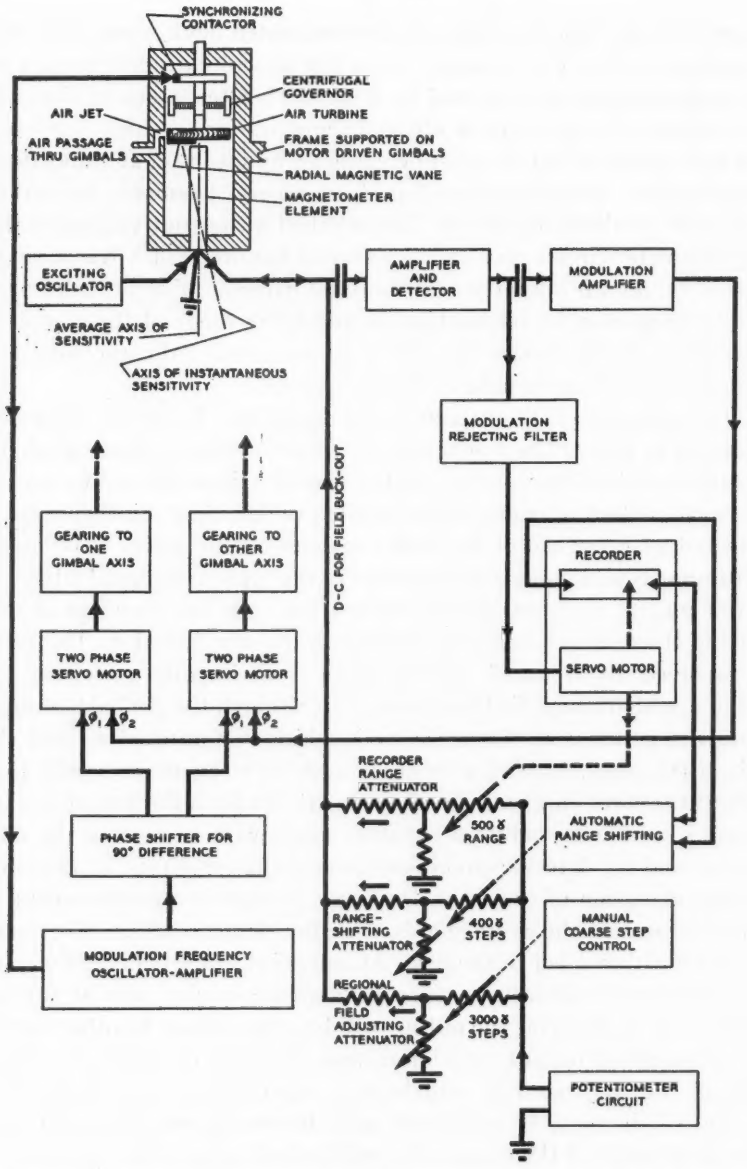

FIG. 3. Diagram of the complete aircraft magnetometer. The whirling magnetic vane causes the magnetometer to sample the earth's field in various directions to detect misorientation, and thereby operate servo motors to restore total-field alignment. Recorder operates continuously and shifts range automatically when the end of its scale is reached. Potentiometer circuits provide for null operation.

The servo motors are small two-phase induction motors. Such motors are phase-sensitive devices. They must be fed two voltages 90 electrical degrees apart to run at full efficiency. Reversing the phase applied to either of their windings will reverse their rotation. Now if one winding of one of the servo motors is fed a voltage of proper fixed phase and amplitude, and if the modulation voltage of variable phase and amplitude is fed to the other winding after suitable amplification, that motor will run with speed and direction dependent on the amount and direction of misalignment. The modulation frequency is determined by the speed of revolution of the air motor and vane, and this is made approximately 60 cycles, which is the proper frequency for the servo motors. The excitation for the first-named winding is taken from an oscillator that is synchronized to the frequency of rotation by means of a contact that closes for an instant during each revolution. The contactor phase is adjusted by turning it to such a position that the servo motor runs in the right direction with full strength for alignment errors in the plane of action of the servo motor, and is unaffected by misalignments perpendicular to this. The other servo motor must be sensitive to misalignments in the perpendicular direction and insensitive to the misalignment components in the first servo motor's direction. This is effected by providing a 90-degree difference in the constantly excited phases of the two servo motors. This 90-degree difference may also be inserted elsewhere in the circuit or be divided between several places provided the total effect is to make the two motors sensitive to displacements 90 degrees apart. In any case the motors break down any misalignment indication into two quadrature components and handle them separately. Phase requirements are not severe, as errors of considerable size merely cause the restoration to occur over a slightly spiral path rather than a radial path.

The recorder works on a null basis as follows: A potentiometer circuit provides a constant flow of current. Any desired fraction of this current may be passed through the secondary winding of the element to annul the magnetization induced in the cores by the earth's field. This is accomplished by means of constant-impedance attenuators which can be separately adjusted without affecting one another appreciably. One attenuator may provide continuous fine adjustment over a range of 500 gammas, which is the scale length of the recorder. The recorder itself can adjust this attenuator automatically. If a change of field occurs, the detector output starts turning the recorder servo motor which moves the pen and also adjusts the recorder

range attenuator until the field change at the detector coil is just bucked out and the recorder stops. This arrangement was suggested by Mr. R. D. Wyckoff. If the magnetic change is great enough to reach the limit of pen motion, a contact is closed at either end of the motion. Closing of one of these contacts starts a motor in the proper direction to rotate a step switch through one step. This changes the range shifting attenuator by one step of 400 gammas, Since these steps are four-fifths of the scale length the pen moves automatically to a point one-fifth of the scale length or 100 gammas from the opposite end of the scale. This prevents shifts from happening too often if the field value happens to fluctuate back and forth at one end of the scale. In case of very large changes of field, as in changing the area of operations, a manual coarse-step attenuator can be set for any value that may occur.

Space does not permit a detailed discussion of many of the interesting problems related to the operation of an airborne magnetometer. Charting the airplane's course over water and all kinds of terrain is a major problem involving the use of some very interesting apparatus. Other interesting problems arose in connection with adapting the gimbal system for efficient operation at all latitudes, obtaining the necessary speed of response without overshoot in the servo motors, providing adequately stabilized voltage regulators, developing a suitable potentiometer circuit, and providing automatic compensation of the magnetometer indications for any servo motor errors caused by abnormally fast motions.

The author wishes to acknowledge direction and assistance by Dr. E. A. Eckhardt and Mr. R. D. Wyckoff as well as suggestions and cooperation of Mr. W. E. Wickerham, Mr. E. W. Westrick, Mr. N. C. Pflaum and other members of the Gulf Laboratory personnel in this development, and to Mr. O. F. Ritzmann, of the Gulf Oil Corp. Patent Department, Mr. J. A. Affleck and others for criticism and assistance in preparing this paper. Permission to publish this paper was kindly granted by Dr. Paul D. Foote.

THE PREMIUM TECHNOLOGICAL DISCOVERY OF PETROLEUM*

E. E. ROSAIRE†

ABSTRACT

Premium technological discovery volume is that achieved in excess of the volume to be anticipated on the basis of price alone and which can be attributed solely to technological advance.

Three degrees of freedom, area, method, and objective, are recognized for the prospector, and these are fixed by choice in any prospecting venture. Continued operation with these three degrees fixed inevitably leads to diminishing returns and, finally, to marginal operations wherein price becomes the primary motivation.

Under such conditions in the past, unfixing even one degree of freedom has led to marked surges in the discovery rate, i.e., to premium technological discovery. Such discovery surges have occurred more than once in the same petroleum province and, not infrequently, the magnitude of the surge has increased rather than decreased with time.

Considerations are presented for a return to premium technological discovery within the United States. Such a return for the method now in most general use, the reflection seismograph, can be expected to follow from unfixing the area degree of freedom through initiating prospecting along the continental shelf. However, such a return for prospecting as a whole, and probably of even greater magnitude, can be anticipated to follow from unfixing the method degree of freedom through widespread application of novelty in prospecting methods.

INTRODUCTION

In a previous study,[1] making use of McCollum's[2] data, this writer determined the relationships between the price per barrel, the exploration activity (in dry holes) and the petroleum discovery volume, over the period 1901–1941 for the continental United States.

The reported discovery volume was 42.7 billion barrels, against which were charged 200.9 thousand dry holes. Of these totals, the established price relationships accounted for 22.6 billion barrels of discovery volume and 166.2 thousand dry holes. The remaining discovery volume (20.1 billion barrels) and exploration activity (34.7 thousand dry holes), i.e., the excess over that calculated on the basis of the

* Read at the annual meeting of the Society, Chicago, Apr. 2, 1946.

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[1] Rosaire, E. E., "Relationships Between Price, Exploration Activity and Petroleum Discovery Volume," The Oil Weekly, Vol. 112, No. 5, January 3, 1944, pp. 26–34, and Vol. 112, No. 6, January 10, 1944, pp. 15–20.

[2] McCollum, L. F., "Some Factors Influencing Declining Rate of Crude Oil Discoveries, etc.," Bull. A.A.P.G., Vol. 27, No. 7, July, 1943, pp. 960–969.

established price relationships, were classified as "premium" discovery volume and exploration activity, and were attributed to the other primary factors of chance and technology.

After making a first order correction for the effect of chance alone by subtracting the 5.1 billion barrels credited to the East Texas oil field, there remained some 15.0 billion barrels and 34.7 thousand dry holes to be credited, and almost entirely in the period 1921–1941, to technological operations at a premium, i.e., over and above the results to be expected on the basis of price alone. Thus, technological operations at a premium were responsible, in only about one-half of the total period, for about one-third of the total discovery volume and required only about one-sixth of the total dry holes (i.e., exploration effort). If the measure of success is defined as the discovery volume per year per dry hole, then that credited to premium technological operations is some four times that to be expected on the basis of operations motivated by price alone.

There is an obvious importance, then, in recognizing the fundamentals which underlie premium technological operations, for those were the circumstances, in the hazard of prospecting, wherein particular operators appear, albeit unknowingly, to have cast their mains with cogged dice. On a national scale, such circumstances resulted in blocking out the equivalent of 75 per cent of our present known reserves at very low costs, obviously an important increment to the nation's warehouse stock.*

As shown in Fig. 14b of the previous report,[1] this premium technological discovery volume took place almost entirely in two major periods, the first from 1924–1931, and the second from 1932–1941. Of these two premium technological peaks, the second reached an even higher level than the first.

THE PROSPECTOR'S THREE DEGREES OF FREEDOM

Every prospecting venture requires choice in the three fundamentals of *area* (the province or locality within which the campaign is carried out), *method* (the primary technique by means of which the

* Conceivably, the premium technological discovery volume credited to technology could have resulted entirely as a result of price levels above those which actually existed. To that extent, technological advance has acted as a price depressant, and can be expected to have a similar effect in the future. This not only is the case in other lines of endeavor in which technology has played a major part but also is the basic principle behind mass production.

drill site for the test well is chosen) and *objective* (the potentially productive zone or the total depth to be evaluated by the test well). Thus, the prospector can be said to have, originally, three degrees of freedom, and, as he exercises choice in only one of the three fundamentals of area, method and objective, he correspondingly restricts his possibilities of discovery.

Thus, if he chooses to base his prospecting venture upon the reflection seismograph, he restricts his possible discoveries to those which can be made by that technique. If he further decides to operate in a given petroleum province, then his possible discoveries are restricted to those which can be made by the reflection seismograph in that region. If, finally, he exercises choice as to the objective (such as the Woodbine of East Texas or the Mississippian of Illinois), obviously he restricts his possible maximum chances of success to a number which is small with respect to discoveries of major importance, and which may become appreciable only if discoveries of minor importance are included. At this point, it is advisable to point out the differences in the perspectives which obtain in the industry.

Restriction to a small number of possible major discoveries is relatively unimportant to the individual, to whom *one* major discovery is a very large number from the standpoint of future income or organizational prestige. However, the increasing national and world requirements are so great that the industry and national perspectives must of necessity be very broad, going far beyond individual or even organizational viewpoints. Such broad perspective shows that the possible maximum of future major discoveries is a number which is none too large even under the most favorable conditions. Thus, such broad perspective must be concerned with the extent to which these degrees of freedom are fixed or free on an industry-wide and national basis.

If, after such initial restriction to a given area, the prospector chooses to venture into another province, then he unfixes or extends his formerly fixed area degree of freedom, and thus increases his number of possible discoveries by the amount which is possible in that extension of his degree of freedom.

Certain circumstances condition these degrees of freedom. Thus, by far the bulk of our petroleum has been produced from sedimentary rocks, so that the practical maximum of the area degree of freedom is limited to the extent of the sedimentary basins. Again, we find and exploit petroleum accumulations at rates far in excess of those at which they are formed in nature, a basic limitation which presages

the foreseeable extinction of the petroleum prospector. Consequently, with all three degrees of freedom fixed by choice, the intensive prospecting characteristic of today can be expected to result in diminishing and even marginal returns within relatively short periods of time.

On the other hand, the objective degree of freedom is limited currently to the depth attainable at reasonable cost by the test well, the last but necessary step in a prospecting venture. However, as progress continues in drilling technique, prospecting is carried out against an increasingly favorable background of greater attainable drilling depths. Therefore, in spite of the discoveries (short of the basement complex) made by previous methods, and the increased hazard thus resulting from the fewer future discoveries possible, a subsequently introduced prospecting method actually may have greater potentialities (for premium discovery) than its predecessors, for interim progress in drilling practice may have materially extended the objective degree of freedom. This consideration may well explain why the second major peak of premium technological discovery volume, extending from 1932 to 1941, surpassed the first major peak at 1924–1931. In any given geological province, such generally improving performance with time can be expected to persist as long as attainable drilling depths increase but remain less than the depth to the basement complex.

PAST CONDITIONS OF PREMIUM TECHNOLOGICAL DISCOVERY

By far the bulk of prospecting has been done under conditions when all three degrees of freedom have been fixed, and the inevitable onset of diminishing returns is like a creeping paralysis. However, perspective shows the transient but very favorable conditions which often appear when even one of these three degrees of freedom is "unfixed."

Consider some of the cases of past outstanding discovery volumes. Previous reference was made to the two major peaks of premium discovery credited to technology.

AREA AND METHOD DEGREES OF FREEDOM

The first peak, from 1924–1930, was made up largely of the discovery volumes which followed from opening the Seminole area and the Permian Basin, two cases of major extension of the areal degree of freedom. The second, from 1932–1940, followed largely from the use of the reflection seismograph, reduced to practice in 1928, a case of major extension of the method degree of freedom. Thus, on a sub-

continental and industry-wide scale, we have illustrations of technological advances resulting in major premium discovery, first, by unfixing the area degree of freedom, and, later, by unfixing the method degree of freedom.

OBJECTIVE DEGREE OF FREEDOM

A third type of technological advance may be expected to result in premium discovery, i.e., unfixing the objective degree of freedom. As an illustration, the East Texas Syncline was the scene of an intensive reflection seismograph campaign for Woodbine structure from 1932–1937. Diminishing and then vanishing returns (from reflection prospecting) made their inevitable appearances, and in 1939 a distinct spirit of pessimism prevailed among the resident geologists. With the subsequent discovery of petroleum in the Paluxy and deeper horizons, a new wave of reflection prospecting spread throughout the province, a clear-cut case where unfixing the objective degree of freedom (through the attainment of discovery in previously unattainable horizons) revitalized both a dormant province and a method previously used therein to the point of vanishing returns.

UNFIXING THE METHOD AND AREA DEGREES OF FREEDOM IN THE GULF COAST

The discovery of salt domes and oil and gas fields in the Gulf Coast of Texas and Louisiana took place in three rather well defined periods. The first followed from prospecting on topographic irregularities and oil and gas seeps. The second followed from the first successful use of geophysical methods, the torsion balance and the refraction seismograph. The third followed from the use of the reflection seismograph. Thus, three discovery surges and two intervening dormant periods in the same province illustrate how province-wide revitalization followed, each time, the successful introduction of a method new to the area, i.e., unfixing the method degree of freedom.

On the basis of accessibility, the Gulf Coast can be divided into the sometimes dry and the always wet areas, the latter being the marsh and water covered areas of South Louisiana. With respect to equipment and methods designed primarily for operations over land the water covered areas were, essentially, a separate province.

Thus, in 1927, when the refraction seismograph began to show diminishing returns in the more accessible parts of the Gulf Coast, it was rejuvenated by unfixing its area degree of freedom through its

successful application to the less accessible portions of the province. About 10 years later, the reflection seismograph also underwent similar rejuvenation when, in turn, its areal degree of freedom was unfixed by similar extension into the same locality.

MAXIMUM RECORDED RATE OF FINDING

Among these instances of unusual success in finding, there is one which stands out as unique. The extension in 1927 of the area degree of freedom for the refraction seismograph was initiated by the highest rate of finding on record, eleven salt domes in nine crew months. The details are as follows.

In the summer of 1927, the refraction seismograph had been used successfully for three years in the Gulf Coast, and had just been introduced with marked success into the East Texas Syncline. Thus the method had been reduced to successful practice, and the technologists had a demonstrated background of competence.

The Louisiana Land and Exploration Company was formed to explore and exploit extensive fee and lease holdings in the marshland, lakes, and bays of south Louisiana. With the exception of some test wells which had been drilled by Colonel E. F. Simms to comply with lease requirements on state owned lakes and bays, the greater part of the Louisiana Land and Exploration Company's holdings were virgin prospecting territory. In fact, Colonel Simms told the writer that he had encountered considerable skepticism in his efforts to explore that water covered acreage, skepticism directed largely at his ideas that salt domes could exist under water.

Two Geophysical Research Corporation crews, completely water borne, were organized for that exploration, the first time that water borne prospecting had been attempted on the grand scale.[3] State laws had to be repealed to legalize the necessary dynamiting in inland waters. New instrumental and field techniques had to be devised. However, the survey was completed on schedule, and, as noted earlier, the result was the highest rate of finding on record, one which still stands as such today.

Of those interesting items, the writer considers as fundamentally pertinent the combination of virgin prospecting territory, rich in the

[3] Rosaire, E. E., and Lester, O. C., Jr., "The Seismological Discovery and Partial Detail of the Vermillion Bay Salt Dome." Bull. A.A.P.G., Vol. 16, No. 12, December, 1932, pp. 1221–1229.

desired objectives, explored by a proved technique with unusual effectiveness in reconnaissance. In essence, this is a case of extension of the area degree of freedom into virgin prospecting territory for a proved and unusually effective reconnaissance technique. On a subprovince scale, the refraction seismograph demonstrated what its province-wide performance would have been had not its hazard of prospecting been increased as a result of discoveries made by earlier and currently competing techniques. The writer considers it no accidental coincidence that the highest rate of finding on record is associated with the successful extension of the area degree of freedom into virgin prospecting territory for a technique characterized by unusual effectiveness in reconnaissance.*

ESTIMATE OF THE PRESENT SITUATION

HISTORICAL BACKGROUND

Within the continental United States, the method degree of freedom has been fixed broadly for a generation in the form of structural prospecting, and specifically for about half that time in the form of the reflection seismograph. If modern petroleum prospecting is considered to have started in 1901 with the discovery at Spindletop, a generation is a relatively large part of such a history. Chronologically at least, the reflection seismograph today stands about where surface geological methods did in 1930.

The reflection seismograph was reduced to practice in Oklahoma in 1928, and, since that time, has been applied, with very favorable results in the way of increased discovery volumes, to several petroleum producing provinces. The list is as follows.

TABLE I. REGIONALLY SUCCESSFUL APPLICATIONS OF THE REFLECTION SEISMOGRAPH

1. Oklahoma	5. California	9. North Louisiana
2. Gulf Coast	6. Kansas	10. Arkansas
3. South Texas	7. Illinois	11. Kentucky
4. East Texas	8. Permian Basin	12. Wyoming
		13. Mississippi

Each of these successful forays by the reflection seismograph resulted in strategic surprise in the way of a province-wide unfixing of

* Just as there are rules for playing football but no rules for winning, that combination in itself was no surety for discovery at a premium. Simultaneously with this very successful foray, another, almost identical, was launched. Two other Geophysical Research Corporation refraction crews, operating for the Dixie Oil Company, also at-

the method degree of freedom (the introduction of a method new to the area), and, while sometimes rejuvenating dormant provinces, successively rejuvenated the method itself (by extending its area degree of freedom).

A complete historical study of these various reflection seismograph campaigns would reveal many instances of more than passing importance. The following, however, are quite pertinent to this study.

GULF COAST REFLECTION CAMPAIGN

In the Gulf Coast, the reflection seismograph followed in the wake of two previously successful techniques. Although thereby the number of future possible discoveries was reduced and the hazard of future prospecting thereby increased, the discovery surge following the introduction of the reflection seismograph surpassed those due to earlier techniques, not only in the number of discoveries but also in individual and total discovery volumes. Thus, Friendswood, Hastings, and Anahuac, credited to the reflection seismograph, are each greater in discovery volume than any individual field discovered by either of the two earlier used techniques. Obviously, the areal extent of the Gulf Coast is so great that even the earlier intensive and quite successful prospecting (by surface indications, the refraction seismograph and the torsion balance) did not critically increase the hazard of subsequent prospecting by the use of the reflection seismograph. In the meantime, interim progress in drilling methods had materially extended the objective degree of freedom.

Today, even after these three successive and increasingly successful prospecting campaigns, the current overall density of oil fields in the Gulf Coast still is far below that which has been established in other producing provinces.

Furthermore, the basement complex has not been reached in this province, and the current progress in drilling methods continues to extend the objective degree of freedom.

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tempted a similar extension of the area degree of freedom into virgin prospecting territory, in that case into coastal Mississippi. The campaign was a complete failure, for there were no shallow salt domes there to find.

However, the real measure of success in prospecting is success itself, not failure, for the hazard of prospecting is ever present. Even so, out of two attempts to extend the area degree of freedom into virgin prospecting territory for the refraction seismograph, not only was one of the two, or 50 per cent of the attempts, successful, but also that success turned out to be the highest on record. What could any prospector ask in the way of better odds?

In view of the established historical pattern for the Gulf Coast, then, the possibility exists not only that a fourth discovery surge may follow, like those recognized to date, from unfixing the method degree of freedom, but also that it may, in turn, top the best to date, that established by the reflection seismograph.

ILLINOIS REFLECTION CAMPAIGN

In Illinois, the absence of effective conservation measures resulted in conditions wherein (as was true of the rest of the United States prior to 1930) annual production figures serve reasonably well for corresponding discovery achievement. The annual production curve for that province is made up of two well defined peaks, with the second topping the first by a good margin. The importance of the first production peak and the pessimism extant after its passing are illustrated by the following quotation, circa 1930. "Twenty years ago, this petroliferous province accounted for approximately 20 per cent of all the oil produced in the United States. Thereafter, with the opening up of prolific areas in the Mid-Continent and in California, the importance of the province became subordinate. In 1929, about 6,000,000 barrels were produced out of a total of over 800,000,000 barrels for the nation, thus representing about 1 percent. During the years from 1889 to date, so many scattered wells have been drilled in the Eastern Interior Coal Basin that no hope remains for any large virgin pools."[4]

Yet, as happened similarly a few years earlier in the Gulf Coast, unfixing the method degree of freedom in Illinois by the successful application of the reflection seismograph resulted, not only in the discovery of individual fields (Salem, Louden, Clay City, etc.) which topped any previous individual discoveries in the first period of finding, but also in a campaign which yielded a much higher number of individual discoveries.

DIMINISHING RETURNS FOR THE REFLECTION SEISMOGRAPH

In each of these successful forays by the reflection seismograph into other geological provinces, the method degree of freedom was fixed (since they were predicated upon the use of the reflection seismograph), the area degree of freedom was fixed (for the individual campaigns were limited to the areal extent of particular provinces), and the objective degree of freedom was fixed either specifically (as

[4] Ver Wiebe, W. A., "Oil Fields in the United States," McGraw-Hill, 1930, page 133.

in the case of the Mississippian in Illinois or the Woodbine in the 1932–1937 East Texas campaign) or generally (i.e., to attainable drilling depths as in the case of California or the Gulf Coast). Obviously, in each case, it was purely a question of time until diminishing and then marginal returns took place.

Consider the situation in the Gulf Coast, where the reflection campaign was initiated in 1929. There the onset of diminishing returns should have been materially delayed for two reasons. First, the unusual extent of that prospecting province should have delayed the inevitable effect of a fixed areal degree of freedom. Second, the great thickness of sediments and the general (rather than specific) objective of reasonably attainable drilling depths (and the great interim progress in drilling technique) should have delayed the inevitable consequence of fixing the objective degree of freedom. As a result, it perhaps is not surprising that, fifteen years after its introduction to the Gulf Coast, current reflection seismograph activity there is close to if not at an all time high. Thus, the province is not dormant, so that the question arises of the extent to which diminishing returns have been evidenced there.

With just that question in mind, a recent study[5] has been made of past and current performance of the reflection seismograph in the Gulf Coast. Two measures of success were determined from published and industry available data.

One of these measures of success is the Initial Risk Ratio, the average number of reflection crew years required to establish one producing structure. These data were fitted to an exponential decrease with time. From such a relationship, it was possible to determine the Halved Initial Risk Time of 9.76 years, the time interval during which there was a decrease of 50 per cent in the crew years required to establish one producing structure. Thus, these data indicate that, over the past 10 years, the initial risk of finding producing structure by the seismograph in the Gulf Coast has halved, a tribute to the endeavor of the exploration technologists and, apparently, justification for their continued primary reliance upon that technique in the Gulf Coast.

The other measure of success is the Gross Reward Ratio, the

[5] Rosaire, E. E., "Reflection Seismograph Performance Along the Gulf Coast," The Oil Weekly, Vol. 113, No. 6, April 10, 1944, pp. 16–24.

average discovery volume, in millions of barrels, credited to the average reflection crew year. Those data also were fitted to an exponential decrease with time. From such a relationship, it was possible to determine the Halved Gross Reward Time of 2.54 years, the time interval during which there was a decrease of 50 per cent in the million barrels discovered per reflection crew year.

These two relationships illustrate the point that (for the reflection seismograph in the Gulf Coast), while the initial risk of finding producing structure (to which must be added the costs of leasing and of the test well) has halved once in 10 years and so decreased by 50 per cent, the gross reward (from which must be subtracted royalties and the cost of development) has halved four successive times in 10 years, and so decreased by about 93 per cent. Obviously, the inevitable outcome can only be "successful" prospecting which cannot be otherwise than a losing venture, and which cannot long continue to replace current withdrawals from warehouse stocks.

Thus, even in the Gulf Coast, where circumstances (great areal extent of the prospecting province and unusual thickness of readily drillable sediments) combined to postpone materially the inevitable consequences of fixing all three degrees of freedom, diminishing returns are current and marginal returns cannot help but follow shortly. It is hardly surprising, then, that the peak of discovery achievement has been passed in provinces of smaller areal extent where the objective degree of freedom was fixed much more specifically. Such was the case in Illinois, where the discovery peak was reached in 1940. Further, it is not surprising that the second industry-wide surge of premium technological prospecting, due primarily to the widespread application of the reflection seismograph, has passed its peak and that, once again, prospecting for petroleum in the United States is at or close to marginal levels, wherein price is the primary motivation.

THE POSSIBILITIES FOR PREMIUM TECHNOLOGICAL PROSPECTING

Certainly, major discovery volume at low cost is at least a long term asset if not a necessity for the industry in view of increasing demands. Such a situation indicates the desirability of a return to technological prospecting at a premium. How can it be best achieved? For that question, the industry, if not the present exploration executives, must find an answer.

THE METHOD DEGREE OF FREEDOM FIXED

CURRENT POTENTIALITIES FOR PREMIUM PROSPECTING BY THE REFLECTION SEISMOGRAPH

The industry has a large plant investment in the reflection seismograph. Although showing diminishing returns even in the Gulf Coast, the technical excellence of the method is steadily improving, as was shown by the exponential decrease in the Initial Risk Rate. Obviously, the industry must give first attention to the current potentialities for premium prospecting by the reflection seismograph.

The strategic considerations are as follows. With one degree of freedom fixed (in this case, the method, i.e., the reflection seismograph), premium discovery may follow by unfixing one or the other of the remaining two degrees of freedom. Thus, the problem resolves itself into the potentialities for reflection prospecting if either (a) the area degree of freedom is unfixed, or (b) the objective degree of freedom is unfixed.

(*a*) *Possibilities of Unfixing the Area Degree of Freedom for the Reflection Seismograph*

Unfixing the area degree of freedom for the reflection seismograph within the continental United States requires that it be successfully introduced into prospecting provinces other than those listed in Table I (where it has been successfully applied).

However, since its reduction to practice in 1928, the reflection seismograph has been tried far more extensively than is indicated by Table I alone, and with far from comparable success, as follows:

TABLE II. MARGINALLY SUCCESSFUL OR UNSUCCESSFUL APPLICATIONS OF THE REFLECTION SEISMOGRAPH

1. Michigan	4. Forest City Basin	7. Dakotas
2. Georgia	5. Edwards Plateau	8. Eastern Colorado
3. Florida	6. Nebraska	9. Upper Mississippi Embayment

Together, Tables I and II include by far the greater part of the sedimentary basins of the continental United States, and show the extent to which the area degree of freedom for the reflection seismograph, since its reduction to practice in 1928, has been restricted through elimination, first, by successful applications and inevitably diminishing returns, and, second, by unsuccessful trials.

However, within the continental United States, there do remain two general areas which offer material possibilities for extending the

area degree of freedom for the reflection seismograph. One of these is Alaska and the other is the Gulf of Mexico.

Alaska

The petroleum producing possibilities of Alaska have been materially enhanced by the extensions to known production which are reported to have taken place as a result of the widely discussed Canol Project. However, the possibility that the reflection seismograph may operate there as a decisive prospecting method awaits the results of actual trial.

Gulf of Mexico

Along and within the margins of the Gulf of Mexico, the reflection seismograph has functioned successfully, and has made substantial contributions in the way of discovery volume. Geologically, the Gulf of Mexico is part of the Gulf Coast Province, wherein has been blocked out a substantial proportion of the nation's warehouse stock. There is every reason for concluding that undiscovered petroleum in the amount of several billions of barrels exists under the Gulf of Mexico, and that the discovery and exploitation of an appreciable part of that probable undiscovered reserve is possible and practical by current methods. Certainly, there is every reason for predicting that major discovery at a premium would surely and swiftly follow if the Gulf Coast reflection crews, yielding diminishing returns there now, were moved out beyond the three mile limit. The remainder of the Continental shelf must be considered as in the same category.

(*b*) *Possibilities of Unfixing the Objective Degree of Freedom for the Reflection Seismograph*

The second way to re-instate premium discovery for the reflection seismograph lies in unfixing its objective degree of freedom. As was pointed out earlier, that actually took place in the case of the East Texas Syncline as a result of interim progress in drilling technique. There the discovery of the production possibilities in the Paluxy and deeper horizons rejuvenated the reflection seismograph in an area where it had been used previously to the point of vanishing returns.

Essentially, this is the approach recently proposed by Denison[6]

[6] Denison, A. R., "Deeper Drilling Prospects in the Mid-Continent," Petroleum Technology, Vol. 6, No. 6, November, 1943. T.P. 1650, pp. 1–8.

when he called attention to the untested thicknesses of sediments within reach of the drill in many producing provinces. Strategically sound, in that it contemplates unfixing one degree of freedom, the approach holds the possibility of rejuvenating now dormant areas. It also is tactically sound, in that it takes due cognizance of practical considerations in limiting the approach to those sediments within reach of the drill. However, in the present state of technical fixation, the opportunities for the discovery of new producing structures probably are limited to those provinces in which the reflection seismograph has worked successfully on shallower horizons. The obviously unattractive feature of this approach is that it involves very high costs for the test wells required.

SUMMARY

POSSIBILITIES FOR PREMIUM DISCOVERY BY THE REFLECTION SEISMOGRAPH

The industry thus faces a condition wherein, as a result of prolonged and intensively pursued method fixation, major producing provinces show diminishing or marginal returns, and go dormant. From the standpoint of premium discovery by the reflection seismograph, with one promising major exception, there appear to be few opportunities for unfixing the area degree of freedom, and the possibilities for unfixing the objective degree of freedom are not very attractive from the standpoint of drilling costs.

UNFIXING THE METHOD DEGREE OF FREEDOM

By contrast, consider the possibilities inherent in unfixing the method degree of freedom, as shown by prospecting history. Now dormant provinces may be rejuvenated, as was true for the Gulf Coast in 1926 and again in 1930, for California in 1932, for the East Texas Syncline in 1927 and again in 1932, and for Illinois in 1936. Virgin prospecting provinces may be vitalized, with unusual opportunities for unusual discovery, as was the case when the refraction seismograph hung up the highest rate of finding on record in the lakes and bays of South Louisiana in 1927.

CONCLUSIONS

With the passing of the second major peak of technological discovery at a premium, the annual discovery volume for the continental United States is approaching or has reached marginal, i.e., price dominated, conditions.

At the present time, the industry has fixed the method degree of freedom by placing its primary reliance upon the reflection seismograph. Under such conditions, a return to technological discovery at a premium within the continental United States reasonably may be expected to follow either from a major extension of the area degree of freedom (such as exploration along the continental shelf), or from an appreciable extension of the objective degree of freedom following from progress in drilling methods.

However, even greater potentialities for technological discovery at a premium can be expected to follow from unfixing the method degree of freedom. There is historical background for expecting that such an achievement would result in discovery volumes which might well surpass those surges of record not only for particular petroleum producing provinces but also for the continental United States.

THE EFFECT OF VELOCITY OF DETONATION ON THE EFFICIENCY OF EXPLOSIVES USED IN SEISMIC PROSPECTING

J. TAYLOR,* G. MORRIS* AND T. C. RICHARDS†

ABSTRACT

Field tests have shown that no significant difference in amplitude or frequency of the first arrivals of refracted waves at distances from 6,000 to 20,000 feet, is found from explosives having velocities of detonation in the range 7,500 to 1,100 metres/second or powers from 61% to 85% blasting gelatine. When a deflagrating explosive was employed there was only a very small decrease in the amplitude of the refracted wave.

INTRODUCTION

It is usual in seismic prospecting to fire the explosive charge at the bottom of a borehole sunk so that the charge lies as far as practicable below the weathered surface layer and to tamp the charge by filling the hole with water and mud.

The explosives used should be capable of withstanding fairly drastic handling in loading the hole, readily combined to make up large charges, able to withstand being left under water pressures, which may reach 100 lb./sq. in. for a period of days, and capable of being initiated to complete detonation by a commercial electric detonator.[1,2] The explosive usually employed are special modifications of the commercial gelatine explosives.[4,5,6] Seismogels and Vibrogels in the U.S.A. and Goebel in this country. Alternatively, powder explosives of the Nitramon type specially packed in tinned iron containers find some application in seismic prospecting.[3]

As regards the velocity of detonation (V.O.D.) and available energy of the explosive, no very definite statement of the best values appears to have been made, but it is generally believed that a high velocity of detonation and energy are desirable in a seismic explosive.

The principal evidence for the former seems to be based on the

* Imperial Chemical Industries Limited.

† Anglo-Iranian Oil Company, Limited.

[1] Heiland, "Geophysical Exploration," Prentice Hall, 1940.

[2] Jakosky, "Exploration Geophysics," 1940.

[3] DuPont, "*Blasters Handbook*," 1942.

[4] Hercules Powder Co., "*Vibrogel for Seismic Exploration*," 1937.

[5] Johnson & Smith, GEOPHYSICS, 1, 1936, p. 228.

[6] Farren & White, GEOPHYSICS, 2, 1937, p. 114.

similar experiments of Johnson and Smith[5] and Farren and White,[6] although the crusher technique adopted by these workers, while indicative of the relative velocity of detonation cannot be considered as equivalent to an actual measurement of the velocities. With regard to the available energy of the explosive, Szczepanski[7] states that explosive charges, the weights of which were adjusted to be inversely proportional to the available energy of the explosive, gave equal amplitudes in a geophysical investigation. To the contrary, Thoenen and Windes[8] investigating the ground vibrations caused by quarry blasting, were unable to distinguish between a wide range of American commercial blasting explosives ranging from 30% to 80% strength, and an analysis, made by one of us, of the data published by Rockwell[9] confirmed this finding.

In view of the comparatively large quantities of explosive used in refraction shooting, it was decided to investigate this question of velocity of detonation by direct field trials, during which the question of explosive strength could also be examined.

EXPERIMENTAL

After some preliminary experimental work, it was decided in the main trials to use three explosives, each of which could be made to react at two different rates, the range being from a velocity of detonation of 7,500 metres/sec. to a true deflagration similar in effect to that obtained in firing a charge of blackpowder. A comparison of the ground motions at distances of 6,000 feet and 19,500 feet from charges of 10 lbs. and 100 lbs., respectively, constituted the investigation.

Details of all the explosives used in these tests are given in Table 1.

SHORT RANGE TEST

The explosives were Geobel No. 2, in the service packing of cardboard former and waxed paper, initiated in the usual way by a No. 6 commercial electric detonator at a V.O.D., under 50 ft. of water measured in a special investigation,* as 5,500 metres/sec., or alternatively, fitted with an axial core of tetryl pellets so that the effective

[7] Szczepanski, Nobel Hefte, 11, 1936, p. 51.

[8] Thoenen & Windes, U. S. Bureau of Mines, R.I. 3353.

[9] Rockwell, "*Vibrations caused by blasting and their effects on building structures*," Hercules Powder Co., 1934.

* It is hoped in the near future to publish an account of the methods used in measuring the velocity of detonation of explosives under hydrostatic pressure.

TABLE 1. DETAILS OF EXPLOSIVES USED IN TESTS

Symbol	Explosive	Type	Average Loading Density gm./cc.	Casing	Priming	Power Ballistic mortar as % age of power given by Blasting Gelatine	Velocity of detonation m./sec.
A.	Geobel No. 2	Nitroglycerine Gelatine	1.50	Wrapped cardboard former	No. 6 Commercial detonator	72	5,500
B.	Geobel No. 2	Nitroglycerine Gelatine	1.50	Wrapped cardboard former	Axial core of tetryl pellets	72	7,000
C.	50/50 Pentolite	Cast	1.6	3.9″ dia. steel case Fig. 1A	1 oz. tetryl pellet	85	7,500
D.	50/50 Pentolite	Granulated Powder	0.88	3.9″ dia. steel case Fig. 1A	1 oz. tetryl pellet	85	3,500–4,400
E.	E.C. Powder	Granular propellant powder	0.43	4.8″ dia. steel case Fig. 1B	1 oz. tetryl pellet	64	2,500
F.	E.C. Powder	Granular propellant powder	0.43	4.8″ dia. steel case Fig. 1B	¾″ axial tube of G. 20 blackpowder	64	Deflagrating
G.	Nobel Rifle Neonite No. 151	Granular propellant powder	0.98	4.6″ dia. steel case Fig. 5	1 oz. tetryl pellet	61	1,100
H.	Nobel Rifle Neonite No. 151	Granular propellant powder	0.98	4.6″ dia. steel case Fig. 5	¾″ axial tube of G. 20 blackpowder	61	Deflagrating

velocity of reaction was 7,000 metres/sec. The other explosives used were in powder form and had to be protected from the water in the borehole by special containers, details of which are shown in Figs. 1A and 1B.

Into the former were loaded 10 lbs. of 50/50 Pentolite (equal parts PETN and TNT melted together), either in the form of granules having an overall loading density of 0.88 gms./cc. and a V.O.D. of

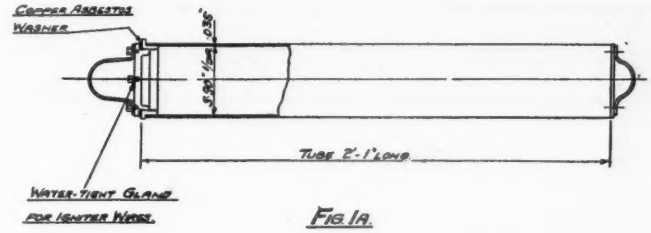

FIG. 1A.

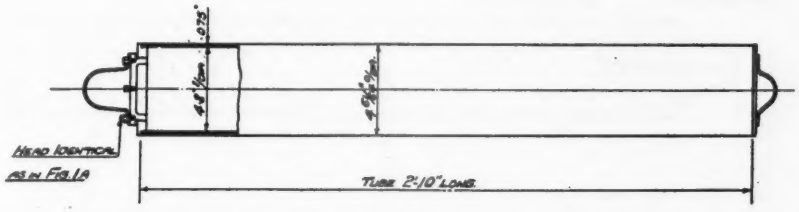

FIG 1B.

FIGS. 1A, 1B. Water-tight pressure containers for explosives (for 10 pound charges).

3,500–4,000 metres/sec., or as a cast charge having the high detonation velocity of 7,500 metres/sec. The power* was the same in each case, viz. 85% of that of Blasting Gelatine.

The third explosive is perhaps of the greatest interest, as we selected for it a bulk propellant powder, which can be made to deflagrate in the same way as when used in a gun by firing it with a blackpowder primer or, if strongly initiated with a tetryl primer, it will detonate with a velocity of detonation of about 2,000 metres/sec-

* "Power" is a technical term used to define the strength of an explosive and is derived from the recoil produced by 10 gm. of explosive fired in a ballistic mortar. It is expressed as a percentage of the figure for Blasting Gelatine which is the most powerful commercial explosive, and does give some indication of available energy.

ond. Owing to the very low loading density of this powder, a larger container had to be used for this 10 lb. charge; details of the container are given in Fig. 1B. The methods of loading and priming the pentolite and powder are shown in Figs. 2A and 2B.

Using these six types of charge, comparative measurements, in duplicate, of the ground motion at a distance of 6,000 ft. were made

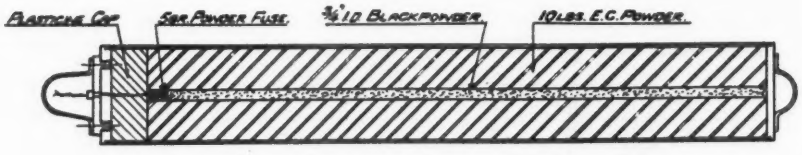

FIG. 2A.

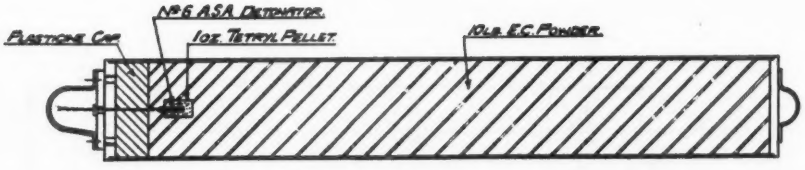

FIG. 2B.

FIGS. 2A, 2B. Water-tight pressure containers, showing methods of loading and priming charges of E.C. powder for deflagration (Fig. 2A) and for detonation (Fig. 2B).

with an electrical refraction outfit, employing six geophones, with natural frequency 2 *CPS* bunched together on the perpendicular bisector of the two rows of charges. Fig. 3. The position of these geophones and the amplifier settings remained constant for each charge, but owing to possible imperfections in geophone "placement" and amplifier magnifications, individual responses shown on any record are not necessarily identical. Fig. 5 shows the records for cast pentolite (Symbol *C*, Table I) and detonated E.C. powder (Symbol *E*) shot from the extreme of Row *b* (Fig. 3), while Table 2 gives the complete data for all these 10 pound charges.

The boreholes were 6 inches in diameter and carried to a depth of approximately 60 feet in a formation consisting of 20 ft. clay followed by soft sandstone; no drilling circulation troubles were encountered in any of the holes, the drilling fluid acting as a uniform tamping. It

was considered that a separation of 60 ft. between each hole of a row would ensure that there would be little likelihood of the conditions at any one shot point being affected by the firing of neighbouring charges. Further, the sequence of firing was arranged so that any effect from this cause would be a minimum.

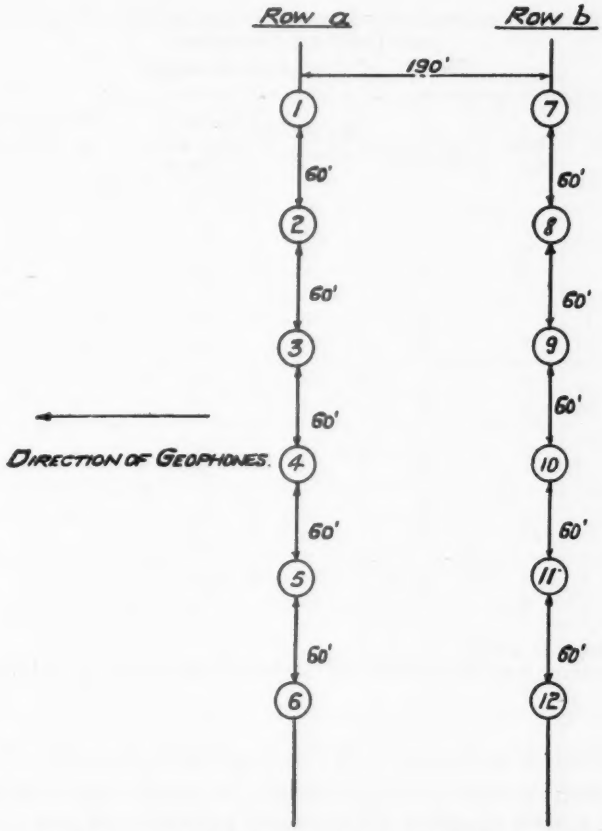

FIG. 3. Lay-out of shot holes for tests with 10 pound charges to geophones at 6,000 ft.

Referring to Table 2 and Figs. 5A and B it is to be noted that, with the exception perhaps of the deflagrating E.C. powder (*F*), the wide differences in velocity of detonation exhibited by the range of charges exert very little effect on the amplitudes of first and later arrivals arriving at the geophones. It appears, however, that the ground selected for the shot point was not wholly satisfactory, for

the agreement of duplicate charges in Row "*b*" with the originals in Row "*a*" was poor; this can hardly be due to the increased distance of only 190 ft. but must largely be related to a change in local shooting conditions between the two rows.

The considerable increase in amplitude when a charge was fired

TABLE 2. REFRACTION SHOT WITH A DISTANCE OF 6,000 FT. BETWEEN SHOT POINT AND GEOPHONES

Borehole—6″ diameter, mud-tamped

Order of Firing	Hole No.	Explosive	Weight of Charge (lbs.)	Depth of lower end of charge (ft.)	Mean amplitude† of first arrival	
					Row a	Row b
1	8	A	10	56		4.1
2	8*	A	10	35		6.9
11	5*	A	10	36	6.7	
5	2	B	10	60	6.1	
10	2*	B	10	45	9.7	
3	7	C	10	60		3.6
6	3	C	10	60	5.1	
8	5	D	10	60	4.9	
12	11	D	10	60		3.5
7	4	E	10	62	5.9	
13	12	E	10	58		3.5
4	9	F	10	55		2.0
9	6	F	10	60	4.6	

* Second shot in hole.

† The energy comparisons would be proportional to the squares of these arbitrary values.

is a used hole is to be noted. In this experiment, however, the second charges were located at depths nearer the upper clay formation and the well known excellent transmission properties of the latter may have largely contributed to the observed effect.

LONG RANGE TEST

In view of the conclusive absence of any effect correlated with V.O.D., it was decided to repeat the comparison of detonating and deflagrating charges over a range more truly representative of refraction shooting and a range of nearly four miles was chosen. For this distance and the particular shot point, it was estimated that 100 lb.

of Geobel No. 2 would be required to give a good amplitude of first arrival. With the low loading density of E.C. powder (Charges *E* and *F* of Table 1) using 5″ diameter containers, the largest for which drilling equipment was available, a column of explosive nearly 30 ft. long would have been needed. This was considered excessive and a search was made for the densest explosive equivalent to E.C. Powder and readily available. Nobel Rifle Neonite No. 151 was found to have

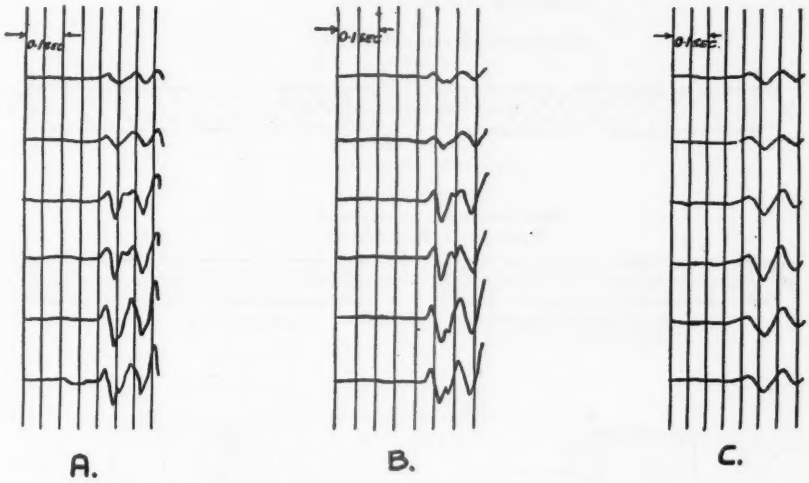

FIG. 4. Typical geophone traces of first arrivals:
A—Trace from charge of 10 lbs. cast Pentolite; (Symbol C, Table I) V.O.D. 7500 meters/sec.; geophone distance 6,000 ft.
B—Trace from charge of 10 lbs. E.C. powder; (Symbol F, Table I) Deflagrating; geophone distance 6,000 ft.
C—Trace from charge of 100 lbs. Geobel No. 2; (Symbol A, Table I) V.O.D. 5,500 meters/sec.; geophone distance 19,500 ft.

the necessary properties and a loading density of 0.98 gm./cc. Unfortunately it was found to be impossible to procure 15′ long containers of adequate straightness for ready lowering into a borehole, and even had those been available, they would have presented some problems in transport after loading. It was accordingly decided to use pairs of $7\frac{1}{2}$′ long containers each holding 50 lb. of charge. Details of these are given in Fig. 5. Although it was not thought that an interval of the order of 0.002 seconds between the firing of the two components would affect the ground vibration generated, a way was found of initiating the two charges within a few microseconds of each

other. This was achieved by firing the charges with Cordtex detonating fuse. As shown in Figs. 5A and 5B, the deflagrating charges were primed with a blackpowder core and the detonating charges with a

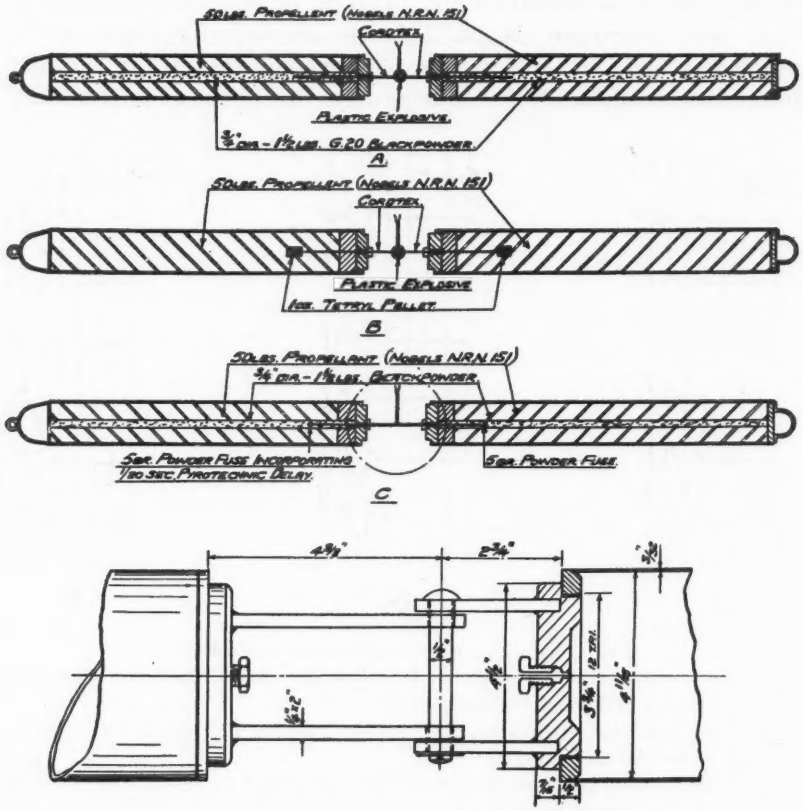

FIG. 5. Water-tight pressure containers for 50 pound charges.
A—Loaded with Nobel Rifle Neonite No. 151, with black powder core (Symbol *H*, Table I).
B—Loaded with Nobel Rifle Neonite No. 151, with tetryl primer (Symbol *G*, Table I)
C—Same as *A*, but with 1/20 Sec. delay in left-hand charge.
D—Detail of joint between containers.

tetryl pellet, both initiated with a length of Cordtex, which was led out of the container by way of a waterproof gland. The free end of the Cordtex was capped with an empty detonator tube filled with waterproofing compound tightly crimped on to the fuse. Before firing, the two lengths of fuse were lashed side by side with two electric deto-

nators and about an ounce of plastic explosive moulded around the joint.

This method of firing made it necessary to find a flexible coupling for the two containers which would not permit the two tubes to come together in loading and damage the fuse. This was achieved by welding pairs of bars $\frac{1}{4}'' \times 2''$ to the top of each container and joining them by a loosely fitting steel bolt held in position by a washer and

TABLE 3. REFRACTION SHOT WITH A DISTANCE OF 19,500 FT. BETWEEN SHOT POINT AND GEOPHONES

Borehole—6″ diameter, mud-tamped

Order of Firing	Explosive	Weight of Charge (lbs.)	Depth of lower end of charge (ft.)	Meam Amplitude† of first arrival
1	A	100	71	5·7 } 5·2
7	A	100	86	4.6 }
2	H	100	63	4.8 } 4·3
6	H	100	71	3.8 }
3	G	100	78	5.8 } 5·4
5	G	100	84	5.0 }
4	H*	100	90	4·7

* Two 50 lb. charges fired 0.05 sec. apart.

† The energy comparisons would be proportional to the squares of these arbitrary values.

split pin. In practice this coupling worked well, the double container being lowered into the bore hole by the drill rig.

In order to investigate the effect of a delay in firing one of the of the pair of charges, one tube of a pair was fitted with a commercial electric powder fuse, while the other had a specially made fuse incorporating a 1/20 sec. pyrotechnic delay (Fig. 5C). As was expected, no effect of this delay could be found in the geophone record.

In this test with the larger charges, the shot holes were located 100 ft. apart, along a straight line, the formation being 35 ft. of clay followed by 20 ft. of shale and 35 ft. of blue marl. Duplication of the charges was again resorted to and the order of firing such that any progressive deterioration of the site would be eliminated from the comparison by averaging the amplitudes given by any charge and its duplicate. The results indicated that deterioration was present and the precaution well justified. Details are given in Table 3, from which it is seen that there is no significant difference in the recorded motion

using explosives having a ratio of V.O.D. of as much as 5 times. The small reduction in amplitude of the deflagrating powders also tends to support the conclusion that the V.O.D. is a minor factor in assessing the merits of explosives suitable for seismic refraction work. Fig. 4C shows a tracing of the record using Geobel No. 2. The first onset has been refracted from the Permian Limestone formation in East Yorkshire at a depth of about 2,300 ft.

THE ACTION OF EXPLOSIVE CHARGES IN BOREHOLES

A detonating explosive can do work on its surroundings by two modes of action: by the shock wave which has a shattering effect and by expansion of the product gases which exert a push on the walls of the borehole.

The proportion of energy in the shock wave is always small; for blasting gelatine in $1\frac{1}{4}''$ cartridges it is only about 8% of the available work,[10] and is proportional to a power of the velocity of detonation so that while explosives which detonate at high velocities (of the order of 7,000 metres/sec.) exert a considerable shattering effect, explosives of lower velocity of detonation, such as the Permitted explosives used in Coal Mines have only a very small fraction of the available energy carried by the shock wave, while deflagrating explosives, of course, produce practically no shock wave at all. Since the energy reaching a distant geophone is practically independent of V.O.D. of the explosive, it follows that the shock wave contributes no useful part of the energy received.

It is suggested that when the explosive charge is fired, the shock wave with its very sharp wave front and preponderance of high frequency components is quickly dissipated in shattering the walls of the borehole (in the case of a rock formation) and in the form of heat. The expanding gaseous products of explosion then push against the unshattered formation, compressing an inner zone until the elastic limit is reached and fracture ensues. Outside this inner zone the formation behaves as a true elastic body and when the gas pressure falls the formation springs back and thus initiates a vibrating source of energy. Compared with the shock wave, the expansion wave lacks strong high frequency components and its dissipation with distance is correspondingly less. The normal absorption properties, of course, result in the well observed increase in the wave length with distance. In

[10] Taylor & Morris, Trans. Farad. Soc., 28, 1932, p. 545.

the case of a clay formation, the dissipation of energy both in the shock wave and the expansion wave is markedly less than in rock formations, but the latter wave is predominant at refraction distances.

It is obvious that to exert any useful action in the ground, the explosive must be wholly converted into a gas in a time so short that the column of tamping cannot move more than a few inches. Very slow combustion merely gives rise to a steady push effect against the tamping without having any useful seismic effect.

Sharpe,[11] amongst others, whose references he cites, has considered the mechanism of explosives in seismic work but he accepts the belief that the V.O.D. is an important factor in reflected motion.

The experiments described above appear to controvert this belief for a refraction distance of 6,000 ft. is equivalent to a very common total length of path in reflection surveying and the larger distance of nearly 20,000 ft. is not outside the equivalent reflection range. If, however, it be conceded that the mechanism of seismic reflection is essentially dependent on the excitation of thin beds into comparatively high frequency vibration, the incident wave should be rich in high frequency components which are more likely to be found in the shock wave. An extension of the investigations of this paper to reflected waves might yield valuable information.

CONCLUSION

By field tests it has been shown that in refraction shooting the ground amplitude registered by geophones is practically independent of the velocity of detonation and not critically dependent on the available energy of explosives used in mud filled boreholes.

The ideal explosive for seismic refraction prospecting must thus have good handling and water-resistance properties, must be initiated by a commercial electric detonator, but provided that complete detonation is achieved, the rate is not of major importance.

The authors thank the Chairman and Directors of the Anglo-Iranian Oil Company Ltd. and of Imperial Chemical Industries Ltd., for permission to publish this paper.

[11] Sharpe, GEOPHYSICS, vol. 7, 1942, pp. 144, 311.

EFFECT OF SURFACE TOPOGRAPHY ON SEISMIC MAPPING*

M. B. WIDESS

ABSTRACT

The presence of rough surface topography in a prospect frequently constitutes a source of error in seismic mapping and poses the question of what computational methods can be applied by which seismic maps may be freed of the effect of surface relief. Various aspects of the problem are described. The use of a plane datum-horizon is generally adequate as a solution of the problem. For greater refinement, the structural map may be modified to account for the overburden effect, the approximate magnitude of which is considered. Further modification may be required when lateral variations in subweathering velocity occur. Statistical analysis for determining the degree of conformity between surface topography and mapped structure at depth is useful in gathering data on the influence of surface topography.

The ever increasing demand imposed on seismic exploration for the discovery for more obscure and smaller structures has heightened the importance of the role played by surface topography in influencing structural mapping. Two independent effects of surface topography are involved, the first of which to be described is the result of differential overburden and the second is the direct or indirect effect on the intrinsic velocity of subweathering material.

I. CONDITION OF HORIZONTAL VELOCITY LAYERS

In computing reflection depth, a specified velocity function may be associated with respect to reflection time for a given structural horizon. The level of datum horizon corresponding to the origin, or zero time, of the velocity function must be chosen and the reflection time adjusted to this datum horizon before the velocity function can be applied.

In the idealized section pictured by Fig. 1, all strata are considered to be horizontal and the velocity below the weathered zone is tentatively considered to be constant within each stratum. Clearly, under such conditions, the irregularity of the ground surface can be eliminated from structural mapping by the use of a horizontal datum-horizon, for example the one shown. Reflection time is then referred to the datum horizon by utilizing the observed subweathering velocity.

* Released by the Stanolind Oil and Gas Company. Presented at the fifteenth annual meeting, Tulsa, and the sectional meeting, Houston, April, 1945.

If, however, the datum horizon is raised at any given shotpoint with respect to adjoining shotpoints, the mapped structure at depth below the shotpoint will respond by dropping to the extent of

$$\delta z = \delta r(v_z/v_{sw} - 1) \qquad (1)$$

with respect to the adjoining depth points, where

δz is the increment of level of the structure.

δr is the increment of level of the datum horizon.

v_{sw} is the subweathering velocity.

v_z is the instantaneous velocity given by the velocity function for depth z, and for simplicity the effect of dip on the velocity function has been neglected.

It is therefore evident that the relief exhibited by the datum horizon is of prime importance to structural mapping.[1,2]

II. OVERBURDEN EFFECT

2.1. *Magnitude of Differential Overburden Effect.* The preceding example was simplified by considering that the velocity layers in Fig. 1 are horizontal, parallel to the strata. In actuality, however, each stratum in the figure experiences a lateral variation in velocity due to a laterally changing overburden, i.e. a varying mechanical compaction by the overlying section with the consequent change in physical properties of the stratum.

Only meager published data are available on the effect of overburden on velocity of sedimentary sections. N. A. Haskell,[3] in an investigation of well velocity in the Tertiary section of California, with depths to 13,000 feet, reports that the present average overburden is responsible for about 78% of the increase of velocity with depth, the remaining 22% being due to that increase of velocity which is associated with greater age of deeper beds. He finds that the magnitude of differential overburden effect for the average of these shale and sandstone sediments is about 0.36 ft./sec. change in instantaneous velocity per foot of depth in section, the effect being about twice as great for the sandstone section as it is for the shale.

[1] John Sloat, "How Not to Find an Oil Field," GEOPHYSICS, Vol. IX, p. 434, Oct., 1944.

[2] Roland F. Beers, "A Problem in Seismic Depth Calculation," GEOPHYSICS, Vol. IV, p. 167, July, 1939.

[3] "The Relation Between Depth, Lithology, and Seismic Wave Velocity in Tertiary Sandstones and Shales," GEOPHYSICS, Vol. VI, p. 318, October, 1941.

Using well velocity in Central Oklahoma, B. B. Weatherby and L. Y. Faust[4] investigated the Pennsylvanian interval between the Hogshooter and the Oswego for an average depth of from 2,100 to 5,700 feet and averaging 750 feet in thickness; the zone consists of

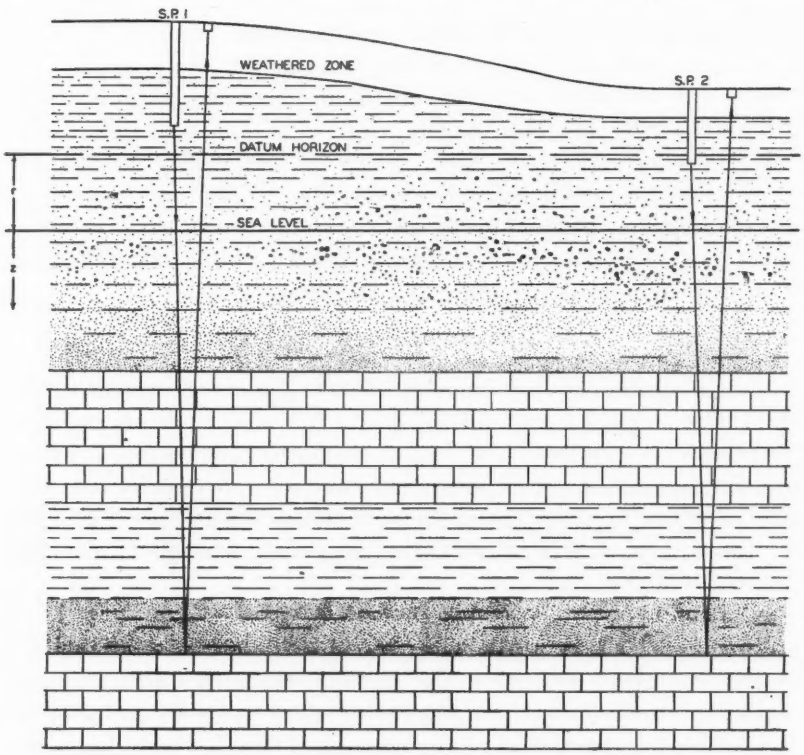

FIG. 1. Idealized section involving differential overburden due to surface topography.

shale, occasional sand, and about fourteen per cent lime. The data show the magnitude of differential overburden effect to be about 0.5 ft./sec. change in instantaneous velocity per foot of depth in section at depths in the vicinity of 3,500 feet.

Another, and this time a direct, measurement of overburden effect was performed by F. Birch and D. Bancroft[5] utilizing samples of vari-

[4] "Influence of Geological Factors on Longitudinal Seismic Velocities," Bul. AAPG, *19*, p. 1, Jan., 1935.

[5] "The Effect of Pressure on the Rigidity of Rocks," J. of Geol., *46*, p. 59 & 113, 1938 and *48*, p. 752, 1940.

ous rocks which were laboratory tested under pressures equivalent to as high as about 100,000 feet of section. Shales and sandstones of as little induration as is characteristic of the sections investigated by either Haskell or Weatherby and Faust were not tested, and the more competent materials which were tested showed considerably less effect

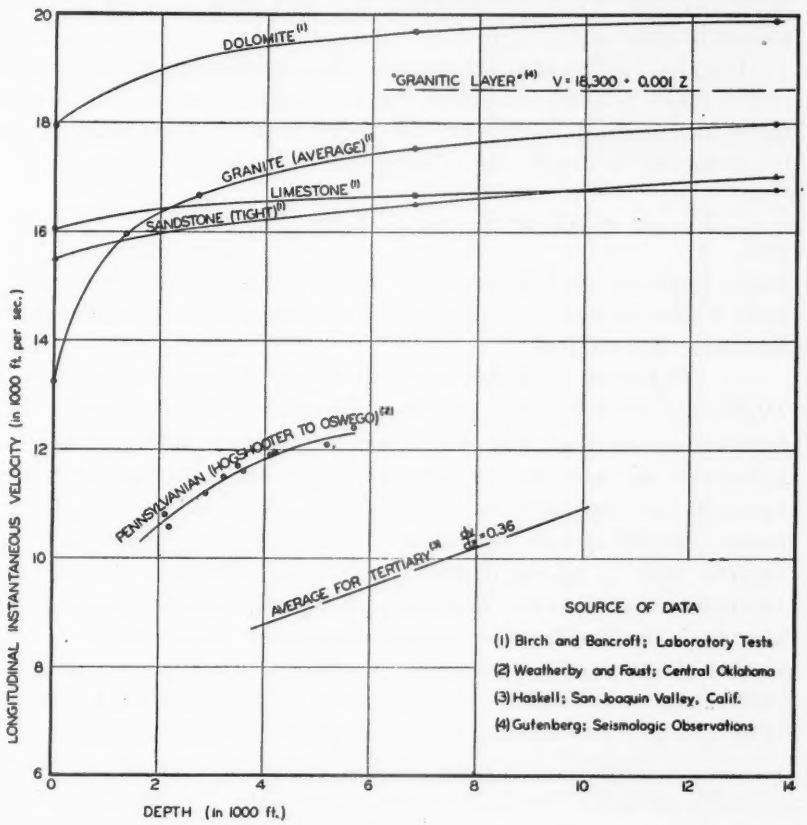

FIG. 2. Some published data on effect of overburden on velocity.

of differential pressure, by a factor from 1/3 to much less for pressure equivalent to about 6000 feet of section. The velocity vs. depth curves are reproduced in Fig. 2, where the data from Birch and Bancroft have been converted by approximating an average density of 2.4 for the equivalent section and by using a ratio of 1.55 between longitudinal velocity and the transverse velocity which was measured. The effect of differential overburden, given by the slopes of these curves,

is shown to decrease rapidly with increasing depth for all of the Birch and Bancroft curves. (The same trend is also shown by the Weatherby and Faust curve, though in this instance the trend is beyond the limit of accuracy of the measurements.) Because the temperature remained fixed throughout the tests, a somewhat lesser effect of depth on velocity than that which was obtained is to be expected for the geologic section in situ.[6]

The small differential overburden effect for deeper and more competent rocks is further indicated by earthquake seismologic observations; for longitudinal waves in the "granitic layer" from about 6,000 to 50,000 feet in depth, the velocity was found to be[7]

$$v = (18{,}300 + 0.001z) \text{ ft./sec.} \quad (z \text{ in feet}),$$

which indicates roughly one-fifth of the average differential overburden effect reported by Birch and Bancroft in their tests of equivalent material and depth.

2.2. *Diffusion of Differential Overburden Effect with Increasing Depth.* The presence of a surface topographic high will produce differential overburden effect which is not confined entirely to the subsurface section immediately below this high, but rather is distributed laterally into the adjoining space. Also, because of this lateral diffusion, the differential overburden effect due to the surface high will decrease with increasing depth below the high. In order to ascertain the influence of surface topography on velocity it is therefore necessary to determine the extent of diffusion which is involved.

The situation will be examined by considering a homogeneous semi-infinite elastic medium on the free surface of which uniform pressure is applied along an infinite strip of width W, which condition would correspond roughly to a steep-flanked narrow plateau on an otherwise flat surface. Though the mechanism of effect of pressure on velocity is not yet fully established, it will be sufficient to assume that the change in elastic properties and density resulting from overburden is produced by the additional volumetric compression, and therefore that the change in velocity is related only to the additional volumetric

[6] F. Birch, "Elasticity of Igneous Rocks at High Temperatures and Pressures," Bull. Geol. Soc. of Amer., *54*, p. 263, 1943.

[7] Beno Gutenberg, "Variation in Physical Properties Within the Earth's Crustal Layer," American Journal of Science, *243A*, Daly Volume, 1945, p. 285.

compression. The magnitude of incremental volumetric compression Δ due to the pressure strip is given by the equation[8]

$$\Delta = \frac{P}{2(\lambda + 2\mu)}\left[\frac{1}{\pi}\tan^{-1}\frac{(W/2) - x}{z} + \frac{1}{\pi}\tan^{-1}\frac{(W/2) + x}{z}\right] \quad (2)$$

where P is the pressure and λ and μ are the Lamé constants. The term in brackets is the diffusion factor $\sigma(x, z)$; the factor represents a

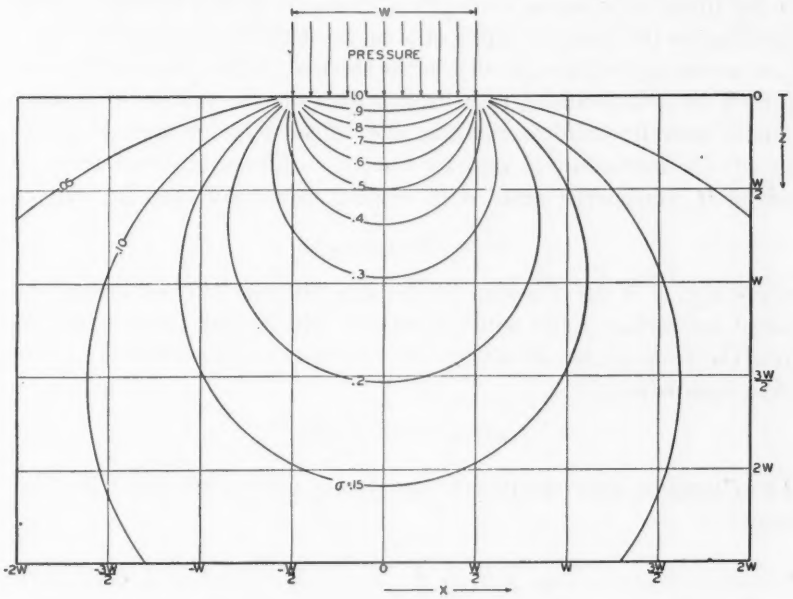

FIG. 3. Diffusion, $\sigma(x, z)$, of volumetric compression resulting from the presence of a pressure strip of width W.

family of circular cylinders which are plotted in Fig. 3 and which reveal the prominent spreading out of the stress. The diffusion is even greater when the pressure area is localized in length as well as in width.

2.3. *Structural Anomaly Due to Surface Relief.* With the knowledge of the relation between pressure and velocity and of the variation of compression with depth below an irregular surface, one is in position

[8] Cf. A. E. H. Love, "Mathematical Theory of Elasticity," Cambridge U. Press, 1934, p. 143.

to determine the erroneous structural relief which would be introduced into a seismic map by the differential overburden.

The basic relation for overburden effect, related to a section of semi-infinite and laterally-uniform extent, is

$$dv/dh = \omega(z) \tag{3}$$

where dv is the differential instantaneous velocity, dh is the differential overburden height, and $w(z)$ is the overburden function applicable to the lithology existing at depth z, this overburden function corresponding to the slope at depth of a curve of the type shown in Fig. 2 (and assuming uniform density in the section). If the differential overburden be now confined to a limited area on the surface of a semi-infinite laterally-uniform medium, the diffusion factor must be introduced; the increment of velocity due to a differential overburden of height H, considered small with respect to z, may then be written

$$\delta v = H\omega(z)\sigma(x, z) \tag{4}$$

where $\sigma(x, z)$ is the diffusion factor. The differential overburden produced by surface relief will introduce a differential travel time $d\delta t$ into the propagation of seismic wave through the distance dz such that, approximately,

$$d\delta t = -(\delta v/v^2)dz. \tag{5}$$

The change in one-way travel-time due to the surface relief then becomes

$$\delta t = -H\int_0^z \frac{\omega(z)\sigma(x, z)dz}{v^2} \tag{6}$$

and the resultant false structural relief which would be mapped is the product of this increment of time and the average velocity to depth z.

For illustration, we shall again consider the case of a long, steep-flanked plateau overlying a uniform horizontal geologic section. For further simplicity, we shall consider that the velocity, without benefit of the differential overburden, is constant at 8,000 ft./sec. and that the overburden function $\omega(z)$ is constant at 0.4 ft./sec. per foot. The relation for the false structural relief δz then reduces to

$$\delta z = \frac{-0.4}{8{,}000} H\int_0^z \sigma(x, z)dz. \tag{7}$$

Performing integration of the relation for $\sigma(y, z)$ given in the preceding section, one obtains the percentage relief $\delta z/H$, which is plotted in Fig. 4 for various depths of mapping. In particular, for a plateau of 4,000 foot width, the false structural relief for a bed mapped at 8,000 foot depth is approximately 15% of the surface relief, and the percentage increases slowly with greater depth. Though

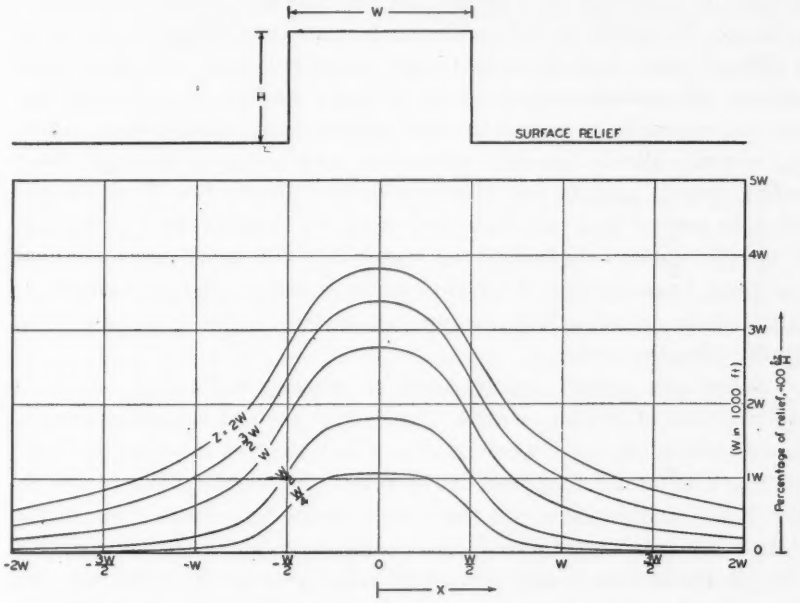

FIG. 4. Example of false structural relief, δz, resulting from overburden due to a surface plateau of height H and width W.

this magnitude is generally not great, where refined measurements are needed and surface relief is rugged, even 15% may be significant.

Certain modification of results would accompany more rigorous computations. For example, though $\omega(z)$ was assumed constant, the evidence of Birch and Bancroft curves favoring a considerably higher magnitude of this function for shallow depths would increase the magnitude of false relief for shallow depths and would lessen the rate of increase of false relief with depth. Also the use of a more realistic velocity function in one which increases with depth rather than one which remains fixed would have a similar effect.

III RELATION BETWEEN SURFACE TOPOGRAPHY AND SUBWEATHERING VELOCITY

The so-called subweathering velocity, the velocity of shallow strata underlying the weathered zone, requires particular attention in interpretation of seismic data because it is involved in adjustment of reflection times to the datum horizon and also because this velocity is frequently observed to undergo sizeable lateral variations within a prospect. The problem of handling such lateral variations is frequently a difficult one. Up-hole time to the necessary depth of penetration beyond the variable velocity layer and to a uniform deep bed is usually too expensive to obtain to be widely used exclusively for weathering control. Where possible, refraction weathering involving a long enough travel path to provide the required penetration is sometimes used. In general field procedure, however, the lateral velocity variation is simply ignored and becomes responsible for some error in final mapping. Investigation of certain aspects of subweathering variations, particularly as related to the ground surface, may prove useful in diminishing the error.

Sometimes surface, or near-surface, geology will supply data on the attitude of shallow strata. The datum horizon can then be disposed paralleling the shallow strata, which may or may not be horizontal. The lateral variation in subweathering velocity due to the relief of the shallow beds will then be eliminated if seismic time to the datum horizon is established. (An analogous lateral velocity variation deep in the section is also created by relief of strata at depth but this is a subject which relates average velocity with structural conformity in the section and will not be entertained at this time.) The near-surface relief may be reflected to some degree in the relief of the ground surface and, to carry the effect a step further, the surface relief may thus indirectly find its way into the mapped structural relief unless a datum horizon paralleling the near-surface relief is used.

In general, surface relief plays an important role in the creation of irregularities in subweathering velocity even when near-surface strata are essentially flat. Accordingly some reflection of ground surface relief will appear in the variations of subweathering velocity and finally manifest itself as structural relief on seismic maps. For example, present stream beds may overlie ancient ones, continuing for considerable depth to produce channels of anomalous velocity. Percolation of water to a degree which is dependent directly or indirectly upon sur-

face relief will modify strata by chemical transformation, by precipitation, or by leaching. Water may be drained away from certain strata near the flanks of an embankment such as to cause lowering of velocity to a magnitude comparable to that of the weathered zone.

Such lateral variations of subweathering velocity may be related to surface relief only at certain locations so that a fixed relation between the two will not exist over an entire prospect. Other subweathering variations may be completely unrelated to the present overlying surface, as in the instance of lens formation governed by topography which was distant or which has been completely modified. In the gross, the irregularities of subweathering velocity may be classified either as coincidental or as non-coincidental with respect to the present ground surface topography which overlies. Final coincidence may be either "positive" or "negative" in that the resulting false structural relief may be either of the same sign as or of the opposite sign from the surface relief causing it. Though the extent of coincidence may vary from location to location, experience gained in the knowledge of coincidence in some areas will aid in predicting expected coincidence elsewhere and, accordingly, a directed investigation of coincidence may prove useful in minimizing at least that portion of anomalous subweathering velocity effect which is coincidental.

IV. STATISTICAL ANALYSIS OF CONFORMITY

The preceding examination of the effect of surface relief has shown that some degree of conformity may be expected between surface topography and the erroneous mapped structural relief at depth, the conformity being produced by the overburden and by direct or indirect influence on subweathering velocity.

In order to gather data on the conformity encountered in field operations, a statistical method can be utilized. A scheme of least-squares analysis presented by A. J. F. Siegert[9] for gravity surveys is also applicable for the present problem. Denoting by h the deviation of surface elevation at a given shotpoint with respect to the mean of elevations of two shotpoints spaced equally on either side, and by z the deviation of the structural elevation at corresponding shotpoints, the conformity between surface and structural relief over the area is given by

[9] "Determination of the Bouguer Correction Constant," GEOPHYSICS, Vol. VII, p. 29, Jan., 1942.

$$K = \frac{\sum_{i=1}^{n} (z_i h_i)}{\sum_{i=1}^{n} h_i^2} \tag{8}$$

and the probable error of this value is

$$\epsilon = 0.67 \left[\frac{1}{n} \left(\frac{\sum_{i=1}^{n} z_i^2}{\sum_{i=1}^{n} h_i^2} - K^2 \right) \right]^{1/2} . \tag{9}$$

In the above, it is found necessary to handle deviations of the center of three points with respect to the two outside ones in order to eliminate regional trends from the computations.

If now it can be determined that geologic information precludes the existence of conformity between surface topography and structural relief at depth in a given area, the statistical analysis will indicate the extent of the role played by overburden effect and that portion of the subweathering velocity variation which is related to surface topography. Statistical runs over numerous areas where no geologic conformity exists will eliminate the chance of accidental conformity and will determine the extent of mapped conformity to be generally considered spurious and therefore to be eliminated. Further discrimination will distinguish between the overburden effect and that of subweathering velocity. The information gained can finally be applied even where some degree of true conformity may exist.

DIMENSIONS AND UNITS OF ELECTROMAGNETIC QUANTITIES

GLENN J. BAKER*

ABSTRACT

A brief history is given of the confusion in the literature in regard to c.g.s. electromagnetic units and some inconsistencies are pointed out. It is contended that most geomagnetic measurements are of the flux density $\boldsymbol{B}$ rather than of $\boldsymbol{H}$, and that the gamma is correctly regarded as equivalent to 10^{-5} gausses. Dimensions of the important electromagnetic quantities and the numerical relations between m.k.s. units and electromagnetic and electrostatic c.g.s. units are set forth. The adoption of m.k.s. units is urged as they are particularly advantageous to engineers.

The main purposes of this paper are to urge the adoption by physicists and engineers of the m.k.s. system of electromagnetic units, and to present a conversion table by means of which a quantity expressed in one system of units may readily be converted into another system.

The centimeter-gram-second systems of units, known as the electrostatic system, the electromagnetic system, and the Gaussian system, have been widely used in scientific literature. Besides these there is in common use the practical system, which arose because the units in other systems were not of convenient size. In 1935 the International Electrotechnical Commission adopted the meter-kilogram-second system of units originally proposed by Giorgi. This system has the advantage of being quite as "absolute" as the old favorites and in addition has units of practical sizes. The change to m.k.s. units has brought attention to bear on the dimensions of electric and magnetic quantities, with the result that dimensional equations now are much more intelligible than they were formerly. The recent literature on electromagnetic theory makes increasing use of m.k.s. units. Unfortunately, writers on purely magnetic subject matter do not appear to have taken up the use of the m.k.s. system.

A considerable amount of confusion exists in regard to the dimensions and names of magnetic units. Probably it will require another generation to clear up the situation entirely. A brief summary of the vicissitudes in the history of c.g.s. magnetic units follows.

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HISTORICAL NOTES ON MAGNETIC UNITS[1,2]

The c.g.s. system was adopted internationally at the Paris Congress in 1881. At the Chicago meeting of the International Electrical Congress in 1893 it was recommended that the c.g.s. system be used for magnetic units but that no names be given to them. After this meeting a Committee of the American Institute of Electrical Engineers recommended the adoption of four names for c.g.s. magnetic units: gilbert for magnetomotive force, weber for flux, oersted for reluctance, and gauss for flux density $\boldsymbol{B}$. It was also recommended that the c.g.s. units be rationalized. At the Paris Congress of 1900 it was decided not to rationalize the units, and two names, though not the ones suggested by the American Committee, were adopted; the maxwell was chosen for flux and the gauss for the magnetic field strength vector $\boldsymbol{H}$. Some misunderstanding occurred at the convention and some of the delegates understood that the term "gauss" was to be applied to $\boldsymbol{B}$.

In 1906 a permanent body, the International Electrotechnical Commission, was organized and one of its committees was concerned with units, standards, symbols, and definitions. However no attempt was made to formulate decisions in regard to magnetic units at subsequent meetings of the International Congress. In the meantime ambiguity grew apace in the literature, especially with respect to the gauss. Some writers employed the gauss to designate $\boldsymbol{H}$ and others applied it to $\boldsymbol{B}$. Some maintained that $\boldsymbol{B}$ and $\boldsymbol{H}$ were quantities of the same kind and applied the name to both. To these authors the magnetic permeability, $\mu=\boldsymbol{B}/\boldsymbol{H}$, was a pure numeric. Other writers considered $\boldsymbol{B}$ and $\boldsymbol{H}$ to be physically different quantities and as a consequence they ascribed dimensions to the permeability. Supporters of either hypothesis can find logical definitions, which uphold their views, in authoritative textbooks.

The International Electrotechnical Commission met in Bellagio, Italy, in 1927 and appointed a committee to report on the question of the gauss. The committee found so much disagreement that no de-

[1] A. E. Kennelly, *Notes on the July 1932 Meeting of the Committee on Symbols, Units, and Nomenclature of the International Union of Pure and Applied Physics, to Discuss Magnetic Units*, Terr. Mag. and Atm. Elect., 37, pp. 447–453 (December, 1932).

———, *The M.K.S. System of Units*, Jour. Inst. Elect. Eng., 78, pp. 235–244 (1936). There is an extensive list of references in this paper. A large part of the historical data is condensed from these two references.

[2] Richard Glazebrook, *The M.K.S. System of Electrical Units*, Jour. Inst. Elect. Eng., 78, pp. 245–247 (1936).

cision was possible. The committee made recommendations to be considered at the next meeting of the Commission. At the meeting in Oslo in 1930 the International Electrotechnical Commission reached the following decisions for electrotechnical purposes: $\boldsymbol{B}$ and $\boldsymbol{H}$ represent different quantities and their ratio, the magnetic permeability, has dimensions; $\boldsymbol{B}$ shall be measured in *gausses* while the unit of $\boldsymbol{H}$ shall be called *oersted;* the unit of magnetic flux shall be the *maxwell* and the unit of magnetomotive force shall be the *gilbert*. No specific dimensions were assigned to the permeability and no name was given to the unit of permeability, but it was stipulated that the ratio μ/μ_0, where μ_0 refers to the permeability of free space, shall be a pure numeric. The name oersted had been applied previously to reluctance. Now oersted was to denote the quantity $\boldsymbol{H}$ and no substitute name was supplied for the unit of reluctance.

The proposition that the c.g.s. system of magnetic units can be based either on the force between two elementary poles or on the force between two elements of current was adopted at the Oslo Convention. It was thought that a pole of strength q_m, in a field $\boldsymbol{H}$, would experience a force $\boldsymbol{F}=q_m\boldsymbol{H}$. It follows that the dimensions of magnetic pole strength must be such that the product $q_m\boldsymbol{H}$ shall be a force. Now it may be deduced from Maxwell's equations that the force on a current of density $\boldsymbol{J}$ is $\boldsymbol{J}\times\boldsymbol{B}$, and consequently the torque on a small magnet (dipole) of moment $\boldsymbol{m}$ is $\boldsymbol{m}\times\boldsymbol{B}$, not $\boldsymbol{m}\times\boldsymbol{H}$, and the force[3] on a magnetic pole is $q_m\boldsymbol{B}$. The dimensions of magnetic pole strength should be such that $q_m\boldsymbol{B}$ (rather than $q_m\boldsymbol{H}$) is a force. Continuing on this basis one discovers that not only the dimensions of magnetic pole strength q_m, but also of magnetic moment $\boldsymbol{m}$, and of intensity of magnetization $\boldsymbol{M}$, are incorrect in the older literature and should be altered to agree with the force equation: $\boldsymbol{F}=q_m\boldsymbol{B}$. Some authors have considered $\boldsymbol{M}$ to have the dimensions of $\boldsymbol{B}$ but others consider $\boldsymbol{M}$ to be dimensionally equivalent to $\boldsymbol{H}$. As a corollary of this situation, long usage has associated the magnetic susceptibility with $\boldsymbol{H}$ whereas it is more logically associated with $\boldsymbol{B}$. The first complete break with tradition in this respect appears to have been made by King.[4] In the light of the present stage of development of electromagnetic theory the names *magnetic flux density* for $\boldsymbol{B}$ and *dielectric displacement* for the electric vector $\boldsymbol{D}$

[3] J. A. Stratton, *Electromagnetic Theory*, McGraw-Hill Book Company, p. 242 (1941).

[4] R. W. P. King, *Electromagnetic Engineering, Vol. 1, Fundamentals*, McGraw-Hill Book Company, pp. 138–140 (1945).

are unfortunate. In order to take the maximum advantage of the symmetry between electric and magnetic theories the magnetic permeability μ should be discarded in favor of its reciprocal. This change has been made by King.[5] The new quantity is denoted by the Greek symbol ν (nu), and is called *reluctivity* or *diamagnetic constant.* Most of the recent authors recognize a parallelism between the natures of $\boldsymbol{E}$ and $\boldsymbol{B}$ and of $\boldsymbol{D}$ and $\boldsymbol{H}$, but there are some exceptions.[6]

According to the statements of the last paragraph the magnetic balances commonly used in geophysical work measure variations in $\boldsymbol{B}$ instead of variations in $\boldsymbol{H}$. In geomagnetic work the gamma is widely used as a unit of convenient size where 100,000 gammas are equal to one gauss, but usually the gamma is considered to be a measure of $\boldsymbol{H}$ rather than of $\boldsymbol{B}$. One sometimes finds the gamma defined as equal to 10^{-5} oersteds. It is the view of this writer that the gamma is correctly defined as a subdivision of the gauss. From the engineering standpoint the distinction between $\boldsymbol{B}$ and $\boldsymbol{H}$ has not been of great importance, since in air $\boldsymbol{B}$ and $\boldsymbol{H}$ have the same numerical values in Gaussian and in c.g.s. electromagnetic units, for in these units the permeability of air is substantially unity.

DIMENSIONS AND MAGNITUDES

In the beginning electric phenomena were considered to be wholly independent of magnetic phenomena and it was natural to devise a separate system of units for each. Later it was discovered that a definite connection exists between electric and magnetic phenomena and that restrictions are imposed on otherwise arbitrary parameters.

The Coulomb law for force between electric charges states that the force is directly proportional to the product of the magnitudes of the charges and is inversely proportional to the square of the distance between them. The constant of proportionality is written as $1/\epsilon$ in the electrostatic system and the equation is

$$F = q_1 q_2/(\epsilon r^2).$$

Accordingly the dimensions of electric charge are deduced to be

$$[q] = \epsilon^{1/2} M^{1/2} L^{3/2} T^{-1},$$

where brackets around a quantity are to be interpreted as "dimensions

[5] *Op. cit.*, pp. 95–98.

[6] See for example, S. A. Schelkunoff, *Electromagnetic Waves*, D. Van Nostrand Company, p. 70 (1943).

of," and in dimensional equations M, L, T, and Q mean mass, length, time, and charge respectively. Fractional exponents in the dimensional equation make it difficult to comprehend. Possibly if the dimensions of ϵ were known and placed in the equation the meaning would be clear.

Nearly all the dimensional equations of electric and magnetic quantities contain fractional exponents. The unintelligibility of the dimensions of electromagnetic quantities is due to the physicist's arbitrariness in maintaining mass, length, and time as the only fundamental entities. At the time of adoption of the m.k.s. system of units the International Electrotechnical Commission did not specify a fourth fundamental quantity. Giorgi proposed the ohm as a fourth quantity but American authors have employed charge, and all electric and magnetic quantities may be expressed in terms of mass, length, time, and charge. Fractional exponents then do not appear in the dimensional equations.

It is unreasonable to suppose that the same quantity can have two sets of dimensions. It follows that the parameters μ and ϵ must have such dimensions that the dimensions of an electric or magnetic quantity are the same in one system of units as in another system. The dimensional equation for the magnetic field $\boldsymbol{H}$ in electromagnetic units is

$$[\boldsymbol{H}] = M^{1/2}/(\mu^{1/2}L^{1/2}T).$$

As a result of the researches of Biot and Savart, it is known that the magnetic field $\boldsymbol{H}$, due to a non-varying current flowing in an infinitely long linear conductor, is directly proportional to the magnitude of the current and inversely proportional to the distance from the current. Let the constant of proportionality be $1/\gamma$. Then

$$[\boldsymbol{H}] = [I]/(\gamma L).$$

Substituting the dimensions of current from the electrostatic system this becomes

$$[\boldsymbol{H}] = \epsilon^{1/2}M^{1/2}L^{1/2}/(\gamma T^2).$$

Equating the two expressions for the dimensions of $\boldsymbol{H}$ one deduces that

$$\gamma(\mu\epsilon)^{-1/2} = L/T = \text{velocity.}^7$$

[7] Cf. J. A. Stratton, *Electromagnetic Theory*, McGraw-Hill Book Company, p. 240, (1941).

If the measurements are made in air (free space), μ and ϵ are to be replaced by μ_0 and ϵ_0, the free-space values. The magnitude of the velocity may be determined by experiment, but no experiment has yet been devised whereby the dimensions of μ_0 or ϵ_0 alone may be ascertained. Whatever the dimensions of the parameters γ, μ, and ϵ, the choice must be made consistent with the above relation. The dimensions of any two of the parameters may be chosen arbitrarily, whence those of the third are fixed. In the m.k.s. system of units γ is chosen to be unity and dimensionless, whereas the remaining two parameters have the magnitudes and dimensions:

$\mu_0 = 4\pi \times 10^{-7} = 1.257 \times 10^{-6}$ henrys/meter.

$\epsilon_0 = 10^7/(4\pi c^2) = 8.854 \times 10^{-12} \cong 1/(36\pi) \times 10^{-9}$ farads/meter.

μ_0 and ϵ_0 refer to free-space values of these quantities.

The ratios μ/μ_0 and ϵ/ϵ_0 are called *relative magnetic permeability* and *relative dielectric constant* respectively.[8] These ratios are, of course, dimensionless and they have the same numerical values in all systems of units. The numerical values of magnetic permeability and dielectric constant tabulated in the literature are relative values in nearly all instances.

The electrostatic and electromagnetic systems of units were based on Coulomb's law and its magnetic analogue. It was logical to write these equations without a factor 4π. The factor 4π then appears in Maxwell's equations. Modern electromagnetic theory recognizes in Maxwell's field equations an expression of the fundamental relations between the electromagnetic field vectors. As such it is desirable to delete the factor 4π from them. Only a few of the quantities concerned are affected by this "rationalization." At its 1935 meeting the International Electrotechnical Commission reached no official decision on rationalization. The m.k.s. system used by recent American authors is rationalized in this sense and the c.g.s. systems are not.

SOME ADVANTAGES OF M.K.S. UNITS

The m.k.s. system is essentially an electromagnetic system with

[8] Alternatively the names *specific magnetic permeability* and *specific inductive capacity* have been used for these ratios. Also one may call μ and ϵ the absolute magnetic permeability and absolute dielectric constant respectively. In this connection an analogy may be noted between density and the electromagnetic quantities μ and ϵ on one hand, and specific gravity and the relative magnetic permeability and relative dielectric constant on the other hand; the former have dimensions and characterize certain aspects of matter while the latter are dimensionless ratios.

units of practical sizes. After a trial extending over several years the writer is convinced of the superiority of m.k.s. units and recommends that others employ them, especially since this system has been officially adopted by the International Electrotechnical Commission and undoubtedly it will be used more and more in the literature of electricity and magnetism. At first the necessity of retaining the free-space symbols μ_0 and ϵ_0 in equations seems to be a definite disadvantage. However, as Stratton[9] has pointed out, it is as difficult to remember the proper position of the factor c (ratio of e.s.u. to e.m.u.), when using Gaussian units, as it is to retain μ_0 and ϵ_0 from the beginning. It is a definite advantage to be able to use a single system for both magnetic and electrical studies, for practical as well as purely scientific investigations, and to have the results expressed in well-known quantities such as amperes and volts. The dimensional equations are free of fractional exponents and no appreciable change is required in terminology. Actually a few of the m.k.s. units are not in common engineering use today. Charge is commonly measured in ampere-hours; one ampere-hour equals 3600 coulombs. Similarly one watt-hour is equal to 3600 joules. The c.g.s. magnetic unit, gamma, is equal to 10^{-9} webers per square meter.

CONVERSION TABLE

The dimensions and numerical relations between units of the m.k.s., electromagnetic, and electrostatic systems are given in the accompanying conversion table. Quantities in the same horizontal row are equal. To change the dimensions to the electrostatic or electromagnetic notation replace the charge Q by its equivalent in the system desired. The numerical values in the column headed "Electrostatic Units" are based on the value $c=3\times10^8$ meters per second for the ratio of electrostatic to electromagnetic c.g.s. units. The best experiments show that the true value is about 2.998×10^8 meters per second. The numerical values given for the magnetic units: pole strength q_m, magnetic moment $\boldsymbol{m}$, and intensity of magnetization $\boldsymbol{M}$, are those obtained by changing from m.k.s. to c.g.s. units. They differ by a factor μ_0 from those given in the older literature. The electromotive force or scalar electric potential V, the magnetomotive force or scalar magnetic potential U, the magnetic vector potential $\boldsymbol{A}$, and the Hertzian vector potential $\boldsymbol{\Pi}$, are sufficiently defined for dimensional purposes by the following equations:

[9] *Loc. cit.*, p. 241.

$$\boldsymbol{E} = \nabla \times \nabla \times \boldsymbol{\Pi} = -\nabla V - \partial \boldsymbol{A}/\partial t.$$

$$\boldsymbol{B} = \mu\epsilon \nabla \times \nabla(\partial \boldsymbol{\Pi}/\partial t) = \nabla \times \boldsymbol{A}.$$

$$\boldsymbol{H} = -\nabla U.$$

DIMENSIONS AND NUMERICAL RELATIONS BETWEEN MAGNITUDES OF M.K.S., ELECTROMAGNETIC AND ELECTROSTATIC C.G.S. UNITS[a]

Quantity	Symbol	Dimensions	M.K.S. units	Electromagnetic units[b]	Electrostatic units[b]
Energy	—	ML^2T^{-2}	1 joule	10^7	10^7
Force	F	MLT^{-2}	1 newton	10^5	10^5
Power	W	ML^2T^{-3}	1 watt	10^7	10^7
Charge	q	Q	1 coulomb	10^{-1}	3×10^9
Charge Density	ρ	QL^{-3}	1 cou./cu.m.	10^{-7}	3×10^3
Capacitance	C	$Q^2M^{-1}L^{-2}T^2$	1 farad	10^{-9}	9×10^{11}
Conductance	G	$Q^2M^{-1}L^{-2}T$	1 siemens[c]	10^{-9}	9×10^{11}
Conductivity	σ	$Q^2M^{-1}L^{-3}T$	1 siemens/m.	10^{-11}	9×10^9
Current	I	QT^{-1}	1 ampere	10^{-1}	3×10^9
Current Density	J	$QL^{-2}T^{-1}$	1 amp./sq.m.	10^{-5}	3×10^5
Dielectric Constant	ϵ	$Q^2M^{-1}L^{-3}T^2$	1 farad/m.	$4\pi\times10^{-11}$	$36\pi\times10^9$
Displacement Density	D	QL^{-2}	1 coul./sq.m.	$4\pi\times10^{-5}$	$12\pi\times10^5$
E.M.F.	V	$Q^{-1}ML^2T^{-2}$	1 volt	10^8	$1/3\times10^{-2}$
Electric Field	E	$Q^{-1}MLT^{-2}$	1 volt/meter	10^6	$1/3\times10^{-4}$
Electric Moment	p	QL	1 coulomb-m.	10	3×10^{11}
Electric Polarization	P	QL^{-2}	1 coul./sq.m.	$4\pi\times10^{-5}$	$12\pi\times10^5$
Hertz Potential	Π	$Q^{-1}ML^3T^{-2}$	1 volt-meter	10^{10}	$1/3$
Impedance	Z	$Q^{-2}ML^2T^{-1}$	1 ohm	10^9	$1/9\times10^{-11}$
Inductance	L	$Q^{-2}ML^2$	1 henry	10^9	$1/9\times10^{-11}$
Magnetic Field	H	$QL^{-1}T^{-1}$	1 amp. turn/m.	$4\pi\times10^{-3}$	$12\pi\times10^7$
Magnetic Flux	Φ	$Q^{-1}ML^2T^{-1}$	1 weber	10^8	$1/3\times10^{-2}$
Magnetic Flux Density	B	$Q^{-1}MT^{-1}$	1 weber/sq.m.	10^4	$1/3\times10^{-6}$
Magnetic Moment	m	QL^2T^{-1}	1 amp.-sq.m.	10^3	3×10^{13}
Magnetization	M	$QL^{-1}T^{-1}$	1 amp. turn/m.	10^{-3}	3×10^7
Magnetic Vector Potential	A	$Q^{-1}MLT^{-1}$	1 weber/meter	10^6	$1/3\times10^{-4}$
M.M.F.	U	QT^{-1}	1 amp. turn	$4\pi\times10^{-1}$	$12\pi\times10^9$
Permeability	μ	$Q^{-2}ML$	1 henry/meter	$1/(4\pi)\times10^7$	$1/(36\pi)\times10^{-13}$
Pole Strength	q_m	QLT^{-1}	1 amp.-meter	10	3×10^{11}
Reluctivity	ν	$Q^2M^{-1}L^{-1}$	1 meter/henry	$4\pi\times10^{-7}$	$36\pi\times10^{13}$

[a] In the table the following abbreviations are used: coul. for coulomb, m. for meter, amp. for ampere, sq. for square, and cu. for cubic. Quantities in the same horizontal row are equal.

[b] This heading may be expanded to read "Number of electromagnetic (electrostatic) c.g.s. units in one m.k.s. unit."

[c] The International Electrotechnical Commission has given the name "siemens" to the m.k.s. unit of conductance. The term "mho" is commonly used in this country for the same unit.

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DISCUSSION

Since the author refers to the actions of the International Electrotechnical Commission (I.E.C.), I would like to point out more specifically what was and was not done in 1930. The important conclusions reached at that time were:

(a) That magnetic induction and magnetic intensity should be considered as quantities of different natures and that, therefore, permeability should be considered as a quantity of still another nature.

(b) That the ratio of one magnetic permability to another magnetic permeability should not be considered to be a physical quantity but instead should be considered to be a numeric or what some prefer to call a pure number.

(c) Having concluded that the ratio of one permeability to another permeability should be considered to be a numeric, they ought to have gone farther and concluded that the ratio of any two quantities of like nature should be considered to be a numeric.

This, however, they failed to do. Thus the impression was left that there is something peculiar about permeability whereby it differs from quantities of other natures to a degree that these other quantities do not differ among themselves.

As a consequence of the failure in 1930 or at a later date to make a clear cut distinction between physical quantities and numerics and the failure to definitely enunciate a set of principles to be followed in defining units, there has resulted some misunderstandings, even among those who advocate the use of the Giorgi system of units.

For example in this paper the dimension of permeability is given as $Q^{-2}ML$ while a unit of permeability is stated to be one henry/meter. Almost certainly it was the intention of some of the delegates to the meeting of the I.E.C. at Torquay in 1938 that permeability like length, mass, and time should be considered as a basic or fundamental quantity of the electromagnetic system of measurements. This would make the dimension of every mechanic, electric, and magnetic quantity some combination of one or more of the quantities length, mass, time, and permeability and require that any unit of a mechanic, electric, or magnetic quantity be defined in effect in terms of a standard of one or more of the quantities length, mass, time, and permeability, provided, of course, that the electromagnetic system of measurements is being considered.

It was also recognized by at least some of the Delegates to the 1938 Meeting that for theoretical purposes any one of several electric or magnetic units might be used as a fourth fundamental unit. Usually the individual units of a system of units are defined in terms of the fundamental or basic units, which in theory, at any rate, are defined in terms of standards of the basic quantities of whatever system of measurements is being used. If then the coulomb is used as a basic unit, where is the standard of quantity in terms of which it is or is to be defined? Different individuals will have different answers to this question but undoubtedly some and presumably most will be of the

opinion that such a standard is nonexistent. If a standard of quantity is nonexistent or if existent but no physical connection with it is implied, definitions of units involving the coulomb as a basic unit are fictions. It is therefore in order to ask: Are definitions of units of any importance? For most geophysicists, electrical engineers, physicists, and instructors in our colleges and universities the answer is no. For the relatively few concerned with the fundamentals of physical measurements, including the standardization of measuring instruments, the answer is emphatically, yes.

As an illustration, when one uses an ammeter in making a physical measurement he may think of an ampere as a coulomb per second. However, in the standardization of the ammeter the unit of current is defined in terms of one or more real—concrete—physically existing standards. Furthermore, some direct or indirect physical connection must be established between the ammeter and the standard or standards. What is amazing about this situation is that, with but few exceptions, those who make physical measurements never need know that they were brought up on more or less fictitious definitions of units. Since this is not generally known, and since usually no attempt is made to segregate real from fictitious deffinitions of u4its, it is not surprising that most every one who tries to arrive at a generally accepted point of view concerning systems of measurements, dimensions, and units encounters a maze of conflicting statements. Then having gotten himself into a bad situation he may feel an irresistible urge to publish something on the subject, without first taking the trouble to get some information from those actually using the standards in terms of which units used in measurements are defined.

If one will examine various recent books and other publications on the fundamentals of electromagnetics such as:

Electromagnetics—A Discussion of Fundamentals by Alfred O'Rahilly, Longmans Green and Co., Cork University Press, 1938;

The Fundamentals of Electromagnetism by E. G. Cullwick, Cambridge University Press, 1939;

Electrical Measurements by H. L. Curtis, McGraw Hill Book Co., 1937;

Principles of Electricity, by Page and Adams, D. Van Nostrand Co., Inc., 1931;

Papers by R. T. Birge in publications of the American Institute of Physics;

The various publications referred to in this paper;

and compare the points of view expressed in these with the points of view in vogue 50 years ago, he will find the confusions of ideas about the same now as then, but much more obvious now than then.

The importance of this paper lies mainly in the emphatic way in which it serves to call attention to this sad state of affairs. Next in importance is the all too short historical account of the international actions concerning units. The stated purpose of the paper is of much less importance. This is because those qualified to make measurements either in the laboratory or in the field, or make analysis, will know how to record their data without placing a string of ciphers either before the first or after the last of their digits.

FRANK WENNER

Department of Terrestrial Magnetism
Carnegie Institution of Washington
Washington 15, D. C., May 31, 1946

AUTHOR'S REPLY

In the course of theoretical work and experimentation in the field it was my experience that the use of the m.k.s. system of units resulted in a saving of labor and also helped to clarify some concepts. The purpose of preparing my paper was, as stated, to present a conversion table and to bring to the attention of others the advantages of the m.k.s. system. These considerations, and an enterprising program committee, constituted my only "irresistible urge to publish something on the subject."

At the outset I would like to point out that my paper is not concerned with physical standards of the fundamental units, or with a *critical* examination of a system already adopted by the International Electrotechnical Commission.

Since all electric and magnetic quantities can not be expressed in terms of mass, length, and time alone, it is evident that these should not be considered the only fundamental quantities. In my paper the coulomb was taken as the fourth fundamental unit. Dr. Wenner raises the objection that if there is no physical standard of charge, then the units based on the coulomb are fictions. It should be emphasized, however, that if some other quantity, such as the permeability, be chosen as the fourth fundamental entity, then Dr. Wenner's objection applies with equal force. The use of charge as a fundamental entity is satisfying in at least two respects: (1) the concept of charge seems quite as fundamental as those of mass, length, and time, and (2) the dimensional equations are free of fractional exponents.

There is in existence a physical standard for an electrical quantity, namely the ohm, which is the resistance of a certain definite column of mercury. One might conclude that it would be advisable to choose the ohm as the fourth fundamental unit, and that in the dimensional equations the symbol Q should be replaced by its equivalent in terms of the resistance R. This procedure leads to more complicated dimensional formulas, and too, the concept of resistance is not as fundamental as it that of electric charge. It is not mandatory that dimensional analyses be made in terms of the physically measurable fundamental units instead of more convenient or theoretically more fundamental quantities. All electric and magnetic quantitites *can* be defined in terms of meters, kilograms, seconds, and ohms. It even may be necessary to do so for a few purposes, but for other purposes it may be more convenient or more illuminating to use some other unit such as the coulomb. Possibly, for experimental purposes at least, the coulomb could be defined in terms of the electrochemical deposition of silver.

Dr. Wenner asks, rhetorically, "Are definitions of units of any importance?," and he concludes that for most geophysicists, electrical engineers, physicists, and instructors in our colleges they are not important. To the extent that we need to have some common concept of what we are talking about, it seems to me that they are important to all of us.

If, as Dr. Wenner implies, definitions of units consist of setting up physical standards for reference, then they are of direct importance to only a few. But it should be noted in this connection that the physical standards themselves occupy a relative rather than an immutable position. For example, the unit of time is the mean solar second. If, as some advocate, the rotational speed of the earth is gradually altered by tidal actions, shifting of masses in mountain building, and other forces, then the unit of time is not constant. Again, the standard meter is represented by the distance between two marks on a certain bar of metal which is *assumed* not to change with time.

In order to know that it remains constant, some means must be devised for measuring it from time to time. The new measuring means then supplants the former standard.

As Dr. Wenner states, there is not complete agreement among advocates of the m.k.s. system. One might add that there are similar differences among adherents to the c.g.s. systems. In my paper the hope is expressed that the situation will be cleared in another generation. Conformity can scarcely be expected without further deliberation and action by the International Electrotechnical Commission. In the meantime we shall continue to pay our utility companies for a given number of kilowatt-hours rather than wait in darkness until their meters can be calibrated in terms of a standard acceptable to all.

GLENN J. BAKER

FOREIGN GEOPHYSICAL ACTIVITIES IN 1945

WILLIAM B. HEROY[1]

The Petroleum Administration for War was concerned with geophysical operations in foreign countries because such work had a direct bearing upon the possibility of discovering new fields and finding new reserves of petroleum. At the beginning of 1945 no one could confidently predict the time when war requirements for petroleum would cease and it was necessary to look ahead for an indefinite period in planning for future oil production. New fields in accessible locations were an important element in the future petroleum supply situation.

At the same time, there was a growing scarcity of some types of equipment, particularly automobiles and trucks, which were needed for the operation of geophysical parties. It was necessary that the equipment which could be procured for such operations be distributed to areas which were not only promising from the standpoint of oil possibilities but from which production, if obtained, could be made available through relatively short and easily constructed transportation facilities.

For these reasons programs for foreign geophysical operations in 1945 were carefully reviewed. The approved program of geophysical operations during that year was published in GEOPHYSICS for July, 1945* Reports on the progress of these operations were currently received from the operating companies and information has been compiled from these which shows the geographic distribution of the parties and the technical methods in use during the first two quarters of 1945. Because of the cessation of military operations the collection of such information was discontinued in the third quarter. From general information which has been obtained it is believed that foreign geophysical operations continued to increase during the last half of the year but no specific figures are available.

The following tabulation gives figures for operations for the first two quarters of 1945, and, for comparison, figures for the last two quarters of 1944, which have been revised from those published last year. The figures do not include parties operating in Canada, Argen-

[1] Director of Foreign Production, Petroleum Administration for War.

* Vol. 10, No. 3, p. 430.

FOREIGN GEOPHYSICAL OPERATIONS BY AREAS AND METHODS

	1 Mexico, Central America, West Indies	2 Caribbean	3 Other South America	4 Eastern Hemisphere	5 Totals
3rd Quarter 1944					
Seismic	4	22	7	3	36
Gravimetric	6	14	2	—	22
Magnetic	—	1	—	—	1
	—	—	—	—	—
Totals	10	37	9	3	59
4th Quarter 1944					
Seismic	4	26	9	2	41
Gravimetric	7	12	2	—	21
Magnetic	—	1	—	—	1
	—	—	—	—	—
Totals	11	39	11	2	63
3rd & 4th Quarters %	17.2	62.3	16.4	4.1	100.0
1st Quarter 1945					
Seismic	6	29	7	3	45
Gravimetric	6	12	1	1	20
Magnetic	1	2	—	—	3
Electric	1	—	—	—	1
Water Gravimetric	1	—	—	—	1
Gravimetric-Magnetic	1	—	—	—	1
Under Water Gravity-Magnetic	—	1	—	—	1
Fluorescent Soil Survey	1	—	—	—	1
	—	—	—	—	—
Totals	17	44	9	4	74
2nd Quarter 1945					
Seismic	5	31	7	2	45
Gravimetric	6	12	1	1	20
Magnetic	1	3	—	—	4
Electric	1	—	—	—	1
Water Gravimetric	1	—	—	—	1
Gravimetric-Magnetic	1	—	—	—	1
Under Water Gravity-Magnetic	—	1	—	—	1
Fluorescent Soil Survey	1	—	—	—	1
	—	—	—	—	—
Totals	16	47	8	3	74
1st & 2nd Quarters 1945 %	22.3	61.5	11.5	4.7	100.0

tina, or Russia, as to which no information was procured. It is believed that the data are otherwise complete. It is impracticable to break down the figures by countries as, in some cases, this might disclose information covering the operations of individual companies. The sta-

tistical information has been compiled under the direction of E. H. Finch, Chief, Statistical Section, Foreign Production Division.

Reports received by this Administration indicate that 561 crews were on the average operated in the United States during the first half of 1945. The total number of crews in foreign service during that period was accordingly about 13 per cent of that number.

PATENTS*

ELECTRICAL PROSPECTING

U. S. No. 2,393,717. D. M. Speaker. Iss. 1/29/46. App. 6/16/44.

Electronic Surgical Metal Body Locator. A metal finder having a small coil in a shielded probe, the probe coil being in a high frequency oscillator circuit whose frequency variations are observed by a beat frequency method.

GEOCHEMICAL PROSPECTING

U. S. No. 2,393,650. H. E. Metcalf. Iss. 1/29/46. App. 6/14/39. Assign. Consolidated Engineering Corp.

Apparatus for Analyzing Hydrocarbons. An apparatus for measuring hydrocarbons in the gas removed from geochemical prospecting samples by bringing the gas in contact with a hot filament and observing the time rate of decay of electron current due to reduction of the work function.

U. S. No. 2,393,674. W. M. Zaikowsky. Iss. 1/29/46. App. 6/26/39. Assign. Consolidated Engineering Corp.

Apparatus for Gas Analysis. A soil gas analysis apparatus having a sample combustion chamber with a heated platinum spiral and a similar chamber containing a blank, the chambers being separated by a click-type diaphragm which is clicked by automatic variations in the volume of the sample combustion chamber, the volume at which clicks occur being recorded.

U. S. No. 2,395,014. E. E. Roper. Iss. 2/19/45. App. 7/30/42. Assign. Stanolind Oil and Gas Co.

Geochemical Prospecting. A method of soil gas analysis in which the gases are desorbed from the soil sample, treated with a strong oxidizing agent which is inert toward hydrocarbons, and then analyzed for significant hydrocarbons.

MAGNETIC PROSPECTING

U. S. No. 2,393,974. R. S. Curry, Jr. Iss. 2/5/46. App. 3/21/42. Assign. Sperry Gyroscope Co.

Gyro Flux Valve Compass System. A gyro compass system having a directional gyro and electrical repeaters, one of the repeaters carrying a flux valve whose signal is fed through a phase sensitive amplifier to the gyro and causes precession which restores the position of the flux valve by means of the repeater system.

SEISMOGRAPH PROSPECTING

U. S. No. 2,392,758. J. P. Minton and R. A. Broding. Iss. 1/8/46. App. 6/27/41. Assign. Socony-Vacuum Oil Co., Inc.

Method and Apparatus for Recording Seismic Waves. A seismograph system in which a variable reactance type geophone modulates a carrier wave and in which amplitude and frequency control are obtained by varying the amplitude and frequency of the carrier.

* Abstracts by O. F. Ritzmann, Gulf Oil Corporation Patent Department.

U. S. No. 2,393,221. R. G. Mercer and D. McW. Taylor. Iss. 1/15/46. App. 10/9/42. Assign. American Cyanamid & Chemical Corp.

Blasting Cap Package. A method of bundling the wires of an electric blasting cap by winding them about two pegs which are subsequently twisted through 90°, the cap and bundle of wires being packaged in a cardboard tube.

U. S. No. 2,393,278. E. S. Bellinger. Iss. 1/22/46. App. 12/5/40. Assign. Hercules Powder Co.

Explosive Package. A dynamite cartridge having a cord and supporting cardboard plate embedded in it, the cord having a loop at the top by means of which the cartridge may be lowered into the hole.

U. S. No. 2,394,990. J. D. Eisler and J. A. Sharpe. Iss. 2/19/46. App. 10/30/37. Assign. Stanolind Oil and Gas Co.

Recording System in Seismic Surveying. A system of seismograph recording in which each geophone output is put on a temporary magnetic record which is immediately run through a succession of reproducers spaced so that the time delay due to motion of the magnetic record represents different step-outs, and the reproductions of various traces are added to give a set of conventional traces of varying directional sensitivity.

U. S. No. 2,395,289. J. Neufeld. Iss. 2/19/46. App. 5/27/43. Assign. Engineering Laboratories, Inc.

Method and Apparatus for Seismic Prospecting. A method of seismograph recording in which the geophone signal is differentiated twice and the ratio of the second time derivative to the original signal is recorded.

U. S. No. 2,395,427. O. S. Petty. Iss. 2/26/46. App. 4/7/41.

Seismic Surveying. A method of controlling both sensitivity and frequency with time in a seismograph recording system by gradually increasing the galvanometer field current through its self inductance, the increase in field also effecting a gradual increase in damping of high frequencies compared to low frequencies.

U. S. No. 2,395,481. H. Hoover, Jr. Iss. 2/26/46. App. 7/24/39. Assign. United Geophysical Co.

Seismic Exploration System. A signal controlled expander system for seismograph amplifiers using thyratrons and relays and in which an intermediate initial sensitivity is used, followed by reduced sensitivity and thereafter an increasing sensitivity to a maximum higher than the initial one.

U. S. No. 2,396,518. R. Martin. Iss. 3/12/46. App. 5/13/44. Assign. Illinois Powder Manufacturing Co.

Explosive Cartridge Assembly. An arrangement for assembling dynamite cartridges end to end by means of a sleeve joining the ends of the cartridges and an internal metal strip with barbs which prevent the cartridges from coming out of the sleeve.

WELL LOGGING AND SURVEYING

U. S. No. 2,391,869. A. M. Bandy. Iss. 1/1/46. App. 6/13/40.

Side Wall Production Tester. A wire line operated side wall sampler which is lowered

into a drill collar having a normally closed side opening, the hinged sample tube being forced into and withdrawn from the formation by vertical motion of the drill stem and passage to the sample chamber simultaneously controlled by a valve in the hinge.

U. S. No. 2,392,357. G. S. Bays. Iss. 1/8/46. App. 6/8/42. Assign. Stanolind Oil and Gas Co.

Well Logging. A method of electrical logging in which the primary log is automatically corrected for variations in hole diameter as determined by calipers or for variations in well fluid resistivity by means of auxiliary conductivity electrodes.

U. S. No. 2,392,683. C. J. McWhorter. Iss. 1/8/46. App. 6/28/43. Assign. Lane-Wells Co.

Side Wall Sampling Tool. A mechanically operated side wall sampler which carries a number of sampling cups in a magazine, the cups being successively forced into the formation and withdrawn into a receptacle.

U. S. No. 2,393,009. M. E. Chun. Iss. 1/15/46. App. 11/3/42. Assign. Lane-Wells Co.

Electrical Well Logging Method and Apparatus. An electric logging system having in the well a current electrode and a series of spaced potential electrodes, the potential electrodes being successively connected by a motor driven switch through resistances, which compensate potential changes due to spacing only, to a measuring apparatus at the surface.

U. S. No. 2,393,092. R. L. Doan. Iss. 1/15/46. App. 3/18/41 Assign. Phillips Petroleum Co.

Apparatus for Gas Analysis of Drilling Mud. An automatic apparatus for continuously extracting and analyzing gas entrained in drilling mud and having a high extraction column, a gas accumulator chamber and a gas analyzer which determines combustible hydrocarbons by adding oxygen and measuring change in resistance of an incandescent filament, the sequence of operations being controlled by a program switch.

U. S. No. 2,395,137. C. V. Millikan. Iss. 2/19/46. App. 11/7/44. Assign. Geophysical Research Corp.

Oil Well Testing Device. A well tester which may be lowered into the tubing of a multi-zone well to record the rate of flow and sample the fluid from a zone.

U. S. No. 2,395,407. J. T. Hayward. Iss. 2/26/46. App. 1/10/42.

Mechanism for Measuring the Movements of Drilling Tools and Pipe. A reel for feeding the measuring line of a drilling rate logging device, the reel having a return spring and a slip clutch to prevent over winding and also an air vane to prevent damage in case the line breaks.

U. S. No. 2,395,617. H. G. Doll. Iss. 2/26/46. App. 3/24/42. Assign. Schlumberger Well Surveying Corp.

Method for Determining the Oil Content of Subterranean Formations. A method of determining oil content of a formation by measuring the salinity of the formation water from a core sample, experimentally determining the curve of resistivity against saturation, and then determining saturation of the formation when encountered in a well from a resistivity log.

U. S. No. 2,396,420. J. T. Hayward and E. H. Cooley. Iss. 3/12/46. App. 4/10/40. Assign. Cooley to Engineering Laboratories, Inc.

Well Survey Apparatus. Apparatus for mud logging of resistivity and viscosity in which temperature variations between ingoing and outgoing mud are compensated, and in which the two recordings on the chart are longitudinally displaced by an amount equivalent to the circulation time so that direct comparison of values may be made.

U. S. No. 2,396,935. J. E. Walstrom. Iss. 3/19/46. App. 11/5/42. Assign. Schlumberger Well Surveying Corp.

Acoustic Logging. A well logging apparatus having spring pressed mechanical contactors which rub on the formation wall and a microphone which picks up the chatter of the contactors.

U. S. No. 2,397,254. G. H. Ennis. Iss. 3/26/46. App. 6/28/35. Assign. One-half to R. V. Funk.

Method and Apparatus for Electrically Coring in Cased Boreholes. A method of electrically logging a cased hole by having a movable electrode centered in the casing and two ground electrodes on the surface, one surface electrode being connected to the casing through a recorder and the other surface electrode connected to the well electrode through a meter.

U. S. No. 2,397,255. G. H. Ennis. Iss. 3/26/46. App. 8/4/36. Assign. One-half to R. V. Funk.

Method of and Apparatus for Electrically Determining the Formation in Wells. A method of electrically logging a cased hole by having a movable electrode centered in the casing and two ground electrodes on the surface, one ground being of a metal electro-positive and one electro-negative with respect to the casing, and observing changes in currents between the casing and grounds and between the well electrode and grounds for various positions of the well electrode.

MISCELLANEOUS

U. S. No. 2,391,966. V. S. Harrison. Iss. 1/1/46. App. 5/18/44. Assign. Consolidated Vultee Aircraft Corp.

Accelerometer. An accelerometer having a liquid filled thin walled cylinder with strain sensitive elements wound around it at each end and the elements connected in a Wheatstone bridge circuit.

U. S. No. 2,392,010. C. Stevens. Iss. 1/1/46. App. 2/17/43.

Flaw Detector for Sheet Material. A continuous thickness caliper for sheet in which a roller moves one inductance of an induction balance and the unbalance is amplified and detected.

U. S. No. 2,392,293. A. C. Ruge. Iss. 1/1/46. App. 2/14/42. Assign. The Baldwin Locomotive Works.

Torque Measuring Apparatus. A system for measuring torque in rotating shafts by having four filament type strain gauges spirally bonded to the outer surface of the shaft and connected as a Wheatstone bridge to slip rings.

U. S. No. 2,392,620. J. W. Sparks. Iss. 1/8/46. App. 8/20/42. Assign. Standard Oil Co.

Identifying Petroleum Products. A method of identifying or marking petroleum products by the addition of a small quantity of fluorescent unbelliferone derivative which may be detected by extracting with an alkaline solution and observing fluorescence under ultraviolet light.

U. S. No. 2,392,662. R. N. Griesheimer. Iss. 1/8/46. App. 3/26/42. Assign. K-C-M Co.

Viscosimeter. A viscosimeter having an annular channel through which fluid is forced at constant velocity and the differential pressure between the ends of the flow channel measured.

U. S. No. 2,392,951. R. G. Salisbury. Iss. 1/15/46. App. 10/14/43. Assign. Pesco Products Co.

Flowmeter. A flowmeter having a metering tank and sight gauge, the liquid level in the sight gauge interrupting light beams to photocells which control an automatic valve and the starting and stopping of a calibrated timer.

U. S. No. 2,393,053. D. R. Moore. Iss. 1/15/46. App. 4/19/44.

Weight Indicator. A dead line tension strain indicator having a dial fastened to the line and a weighted chain fastened to the line some distance above the dial and wound around the shaft of a pointer on the dial.

U. S. No. 2,393,069. F. C. Rushing, H. C. Werner and B. Cametti. Iss. 1/15/46. App. 12/9/41. Assign. Westinghouse Electric Corp.

Vibrograph. A mechanically recording vibrograph having a large mass sprung to the case and a light prod sprung to the mass, clamps selectively fastening either the large mass or the prod to the case so that the instrument may be used either as a contact vibrometer or as a seismograph.

U. S. No. 2,393,197. R. Scott. Iss. 1/15/46. App. 3/22/44 and 12/20/44. Assign. General Electric Co.

Remote Reading Temperature Instrument. A circuit and indicator for an electric resistance thermometer having the resistance element connected in a bridge network so as to control the current division between two opposed coils on a magnetic core, the position of the salient pole on the core being indicated by a magnet and pointer.

U. S. No. 2,393,225. B. A. Andalikiewicz. Iss. 1/22/46. App. 10/23/42. Assign. C. E. Hovey.

Flaw Detecting Method. A method of testing articles by dropping them against an anvil, measuring either the frequency or amplitude of sound produced and comparing with that produced by a standard article.

U. S. No. 2,393,559. P. M. Pappas. Iss. 1/22/46. App. 6/29/43.

Timing Device. An operation timer having a hydraulic dash pot whose piston has an auxiliary disk valve which changes the flow restriction when piston motion is reversed.

U. S. No. 2,393,669. E. P. Wheaton and R. H. Ostergren. Iss. 1/29/46. App. 10/21/41. Assign. Consolidated Engineering Corp.

Strain Measuring System. A modulated carrier type of strain recording system in which a variable resistance strain element is excited in a bridge circuit of which one branch is the exciting transformer and which uses dummy resistance elements for temperature compensation.

U. S. No. 2,393,714. E. E. Simmons, Jr. Iss. 1/29/46. App. 7/23/41.

Strain Gauge. A filament type strain gauge in which the filament is openly strung between the ends of an elastic bow carrying the lead wires so that the filament wire itself may be bonded to the test piece.

U. S. No. 2,393,750. D. E. Carter. Iss. 1/29/46. App. 9/10/43.

Impact Dampener. A pressure fluctuation dampener for the mud line, the pulses being taken up by a piston acting against either a spring or compressed air.

U. S. No. 2,393,977. S. E. Dawson and J. R. Pimlott. Iss. 2/5/46. App. 5/25/44.

Electronic Null Indicator for Electromagnetic Micrometers. A null indicator for a bridge type strain gauge using two triodes whose plates are excited from the same a-c which supplies the bridge and whose grids detect the bridge unbalance.

U. S. No. 2,393,996. A. C. Layton. Iss. 2/5/46. App. 10/31/44.

Method of Detecting Flaws. A method of detecting surface flaws by immersing the article in a colored liquid, applying suction to remove air from the flaw, applying pressure to force the liquid into the flaw, then removing the article from the liquid and applying suction to draw out the colored liquid.

U. S. No. 2,394,079. B. F. Langer and K. L. Wommack. Iss. 2/5/46. App. 5/5/44. Assign. Westinghouse Electric Corp.

Strain Measuring System. A system for measuring strain in a rotating shaft using a variable air gap balanced impedance type strain detector and a ratio meter as an indicator.

U. S. No. 2,394,152. G. W. Coon. Iss. 2/5/46. App. 10/10/42. Assign. Magnaflux Corp.

Means for Magnetic Testing. Apparatus for longitudinally magnetizing a small test piece with a coil and circularly magnetizing the piece by passing a current through it, the coil and the current contacts being connected to the two sides of a center-tapped transformer through half wave rectifiers so that they are energized alternately.

U. S. No. 2,394,286. W. C. Blaisdell. Iss. 2/5/46. App. 1/24/42. Assign. National-Simplex-Bludworth, Ind.

Interval Meter. An interval meter for echo sounding apparatus having a continuously rotating indicator scale which is illuminated stroboscopically at the end of the interval, and whose scale range is changed by changing scale speed.

U. S. No. 2,394,287. T. F. Bludworth. Iss. 2/5/46. App. 8/21/41. Assign. National-Simplex-Bludworth, Inc.

Interval Meter and Indicator Therefor. An interval meter for echo sounding appa-

ratus in which a rotating spiral shutter passes a slit which is illuminated at the end of the interval.

U. S. No. 2,394,288. T. F. Bludworth. Iss. 2/5/46. App. 8/21/41. Assign. National-Simplex-Bludworth, Inc.

Interval Meter and Indicator Therefor. An interval meter for echo sounding apparatus having a continuously moving belt carrying mirrors on part of its length, the mirrors reflecting light onto a scale, and the light going out at the end of the interval.

U. S. No. 2,394,455. W. R. Koch. Iss. 2/5/46. App. 12/28/43. Assign. Radio Corp. of America.

Method of and Means for Measuring Mechanical Impedance. A method of measuring mechanical impedance of a moving system by applying it as a load to a vibrating wire one quarter wave length from the fixed end and observing the changes in position and magnitude of the standing wave pattern.

U. S. No. 2,394,461. W. P. Mason. Iss. 2/5/46. App. 10/6/43. Assign. Bell Telephone Laboratories, Inc.

Means for and Method of Measuring the Impedance and Reflection Coefficients of Surfaces. Method and apparatus for determining the reflection coefficient of a material surface by immersing it in a tank of liquid, directing a plane compressional wave normal to the surface, moving the wave transmitter toward and away from the surface and measuring the electrical input to the transmitter at maximum and minimum points.

U. S. No. 2,394,549. W. H. Howe. Iss. 2/12/46. App. 3/23/44. Assign. The Foxboro Co.

Specific Gravity Measuring Device. A double bubble tube apparatus for measuring the specific gravity of liquids in which most of the differential bubble pressure is balanced by also bubbling the air through a standard liquid.

U. S. No. 2,394,703. E. Lipson. Iss. 2/12/46. App. 7/6/42.

Soil Analysis by Radiant Energy. A method of soil or well cutting analysis in which samples are subjected to gamma radiation and the intensity of transmitted radiation measured or compared with that of a standard sample.

U. S. No. 2,394,974. J. E. Bevins. Iss. 2/19/46. App. 5/19/43. Assign. Bendix Aviation Corp.

Accelerometer. An aircraft accelerometer having an inertia mass on a cord which wraps around a pulley on the indicator shaft and an indicating system which registers maximum, minimum and instantaneous values.

U. S. No. 2,395,127. O. Kornei. Iss. 2/19/46. App. 4/19/44. Assign. The Brush Development Co.

Time-Measuring Instrument. An interval timer in which signals are magnetically recorded on a constant-speed disk, the start signal starting and synchronously pacing a time clock and the end signal stopping the clock to indicate whole disk revolutions; the fractional revolutions then being indicated by causing the two disk signals to flash lamps illuminating a rotating scale.

U. S. No. 2,395,166. S. B. Collins. Iss. 2/19/46. App. 12/24/42. Assign. The Astatic Corp.

Transducer. A permanent magnet electrodynamic type transducer having non-magnetic fingers extending from the outer pole piece to the inner pole piece to impart rigidity and a felt seal to keep dust out of the air gap.

U. S. No. 2,395,192. R. H. Ostergren. Iss. 2/19/46. App. 1/17/44. Assign. Douglas Aircraft Co., Inc.

Resistance Thermometer. A quick responding fine filament type electrical resistance thermometer in which the effect of strains is compensated by using two mechanically similar filaments having different temperature coefficients of resistance.

U. S. No. 2,395,902. C. R. Nisewanger and F. W. Brown. Iss. 3/5/46. App. 2/27/45. Assign. U. S. A.

Electronic Chronoscope for Measuring Rates of Detonation. A circuit for measuring very short time intervals in which electronic keying and electronic relay circuits close the charging circuit of a condenser at the beginning of the time interval and open the circuit at the end of the interval and the voltage is measured with a vacuum tube voltmeter.

U. S. No. 2,396,112. H. C. Morgan. Iss. 3/5/46. App. 9/2/43. Assign. Curtis Engineer Co.

Radio Navigation System and Method. An airplane navigation system using a microwave transmitter on the plane, a series of high efficiency reflectors marking the course on the ground, and a scanning and indicating system which shows the position of the reflectors on a c-r tube screen on the plane.

U. S. No. 2,396,222. L. L. Foldy. Iss. 3/5/46. App. 10/26/42. Assign. The Brush Development Co.

Sound Receiving System. A highly directional linear array of microphones in which the relative sensitivities of the individual units are proportional to the binomial coefficients.

U. S. No. 2,396,224. M. Artzt. Iss. 3/12/46. App. 6/16/43. Assign. Radio Corp. of America.

Oscillation Generator. A resistance-capacity oscillator for driving a tuning fork and whose rate is controlled by the fork, the combination having high frequency stability.

U. S. No. 2,396,394. H. Shaw. Iss. 2/12/46. App. 12/2/41 and 5/26/43.

Apparatus for Determining the Roughness of Surfaces. A roughness tester in which a blunt nosed stylus and a sharply pointed stylus are moved across the surface and their relative vertical motions indicated.

U. S. No. 2,396,519. F. Massa. Iss. 3/12/46. App. 10/31/39. Assign. Radio Corp. of America.

Electroacoustical Apparatus and Method of Using the Same. A pressure gradient responsive directional microphone made of a hollow cylinder with a diaphragm at each

end, the diaphragms being connected together and to an internal moving oil in a permanent magnet field.

U. S. No. 2,396,540. R. Stansfield. Iss. 3/12/46. App. 3/10/42 and 1/21/43.

Means for Detecting and Measuring Torsional Vibrations. An electromechanical torsional vibration detector which has a wound armature coupled to the rotating shaft and a freely floating field structure which comes up to a constant average speed, the a-c generated by the relative motion being observed on an oscilloscope.

U. S. No. 2,396,652. R. V. Heilman. Iss. 3/19/46. App. 1/27/42 Assign. Wall Wire Products Co.

Brush Guard and Method of Making Same. An open frame for protecting the radiator and headlamp of a vehicle from brush and which is assembled by resistance welding.

U. S. No. 2,396,691. R. R. Galbreath. Iss. 3/19/46. App. 6/19/41. Assign. Bell Telephone Laboratories, Inc.

Condenser Transmitter-Amplifier System. An amplifier system for use with condenser microphones in which a negative feedback circuit from output to input includes the microphone and eliminates the effect of microphone or cord capacity on response characteristic.

U. S. No. 2,396,699. H. C. Hays and S. L. Quimby. Iss. 3/19/46. App. 9/24/41.

Detecting Device. A vibration detector for an acoustic submarine mine in which a diaphragm with a small rod imparts rotation to a small wheel on a hair spring, the wheel pivot supports being elastically supported to partake of the vibration and so eliminate sticking.

U. S. No. 2,396,703. B. R. Kamler and D. L. Elam. Iss. 3/19/46. App. 7/21/43. Assign. A. Crossley.

Pickup. An electromagnetic cylinder pressure pickup for internal combustion engines using a permanent magnet with a wound soft iron pole piece terminating close to a pressure diaphragm.

U. S. No. 2,396,722. P. T. Russell. Iss. 3/19/46. App. 12/9/36.

Acoustical Apparatus. A remotely controlled electrically operated mounting for an underwater transmitter or receiver which will extend or retract the device from the bottom of the ship and also rotate it into a desired direction.

U. S. No. 2,396,724. A. F. Spilhaus. Iss. 3/19/46. App. 4/18/41. Assign. Submarine Signal Co.

Bathythermograph and Sea Sampler. An apparatus to be lowered into the ocean and which mechanically records a temperature-depth curve and also takes sea water samples at predetermined depths which are indicated on the curve.

U. S. No. 2,396,898. H. F. Storm. Iss. 3/19/46. App. 6/7/44. Assign. Chicago Flexible Shaft Co.

Timing Apparatus. A two interval timing apparatus for metal heat treating and quenching operations in which the first interval is determined by the discharge of a

condenser and the second interval by the charge of the condenser through a different resistance, the condenser being in the grid circuit of a tube having a relay in its plate circuit.

U. S. No. 2,396,929. J. P. Putnam. Iss. 3/19/46. App. 9/18/43. Assign. The Reece Button Hole Machine Co.

Time Indicator. An airplane flight time indicator having an elastic scale graduated in time which may be stretched over a map between two clamps fastened to the map case surface by suction cups.

U. S. No. 2 397,071. D. G. C. Hare. Iss. 3/19/46. App. 9/27/41. Assign. The Texas Co.

Radiation Detector. A Geiger-Muller counter type of gamma ray detector in which a number of anode wires pass through alligned holes in a series of cathode surfaces, the latter being either parallel plates or zig-zig strips or an edge wound spiral strip.

U. S. No. 2,397,072. D. G. C. Hare. Iss. 3/19/46. App. 1/15/42. Assign. Texaco Development Corp.

Radiation Detector. A Geiger-Muller counter type of gamma ray detector in which a number of anode wires pass through aligned holes in a series of internesting cathode surfaces, the latter being in the shape of cones or annularly corrugated rings.

U. S. No. 2,397,073. D. G. C. Hare and G. Herzog. Iss. 3/19/46. App. 11/2/40. Assign. The Texas Co.

Radiation Detector. A Geiger-Muller counter type of gamma ray detector in which a number of parallel anode wires pass through the space between two parallel metal sheets or in the annular space between two concentric cylinders.

U. S. No. 2,397,074. D. G. C. Hare and G. Herzog. Iss. 3/19/46. App. 10/16/41. Assign. The Texas Co.

Radiation Detector. A Geiger-Muller counter type of gamma ray detector in which a number of spaced parallel plates are mounted on a frame and anode wires are stretched between the plates back and forth between posts.

U. S. No. 2,397,075. D. G. C. Hare and G. Herzog. Iss. 3/19/46. App. 10/16/41. Assign. The Texas Co.

Radiation Detector. A Geiger-Muller counter type of gamma ray detector in which anode wires are strung between spaced parallel plates and in which spurious counts due to insulation leakage are avoided by using a guard plate.

U. S. No. 2,397,219. W. R. Taliaferro. Iss. 3/26/46. App. 3/18/44. Assign. Westinghouse Electric Corp.

Timing Device. A delayed action relay in which the relay armature is elastically connected to the contact arm, motion of the latter being delayed by the time required for cold flow of a plastic support to take place.

DISCUSSIONS AND COMMUNICATIONS

INTERNATIONAL SCIENTIFIC CO-OPERATION

The gradual easing of restrictions on travel and on the general release of scientific discoveries has made it practicable once more to arrange international meetings of men of science. The general Assembly of the International Council of Scientific Unions will meet in London on July 22–24, 1946. Meanwhile its Executive Committee has held a meeting in London attended by representatives of most of the International Unions adhering to the Council.

In welcoming the Committee at its opening session Dr. A. V. Hill, Foreign Secretary of the Royal Society, pointed out that science in its own interest must remain an international concern and that the future of civilization itself depended upon the close co-operation of scientific men throughout the world. Taking as an example the field of medicine and the high ethical principles which had been developed therein he emphasised the need for a common standard of ethical behaviour in science. "In standards of truthfulness and integrity, in readiness to co-operate with other scientists of good will everywhere, and in refusal to use the common knowledge, prestige and power of science for base, harmful and selfish ends, scientists should feel themselves bound by an honourable and unbreakable obligation."

The heavy toll of recent years on those prominent in the field of international science was revealed by the list of members of the Committee who had died since its last meeting: Il Marchese Marconi and Baron Joji Sakurai: Vice-Presidents: Sir Arthur Eddington, President of the International Astronomical Union: Prof. Nicola Parravano, President of the International Union of Chemistry; Sir Albert Seward, President of the International Union of Biology; Dr. Philippson, General Secretary of the International Union of Physics, and General Bourgeois, former Vice-President, representing the International Union of Geography.

The President of the Council, Prof. C. Fabry, had been compelled to resign on account of ill-health (he has since died) and Dr. H. R. Kruyt was elected President, Dr. Elmer D. Merrill being elected Vice-President in his place.

The International Council, or rather its predecessor the International Research Council, was created after the first World War and took as its main task the creation of the various international scientific unions. In the early days the council exercised a certain amount of control over these unions in such questions as membership and finances. As the individual unions became established and strong this control proved irksome and a change took place in the relative positions of the Council and the Unions, largely the work of the then General Secretary of the Council, the late Sir Henry Lyon. Now it would be fairer to say that the Unions control the Council, the majority of the members of the Executive Committee being the representatives of the Unions. The Officers and two members of the Executive Committee only are appointed by the General Assembly at which the national adhering organisations have a preponderating vote.

The international unions meet in General Assembly as a rule once in three years for discussions on the field of knowledge lying within their purview; by means of numerous committees of specialists work is carried on between the meetings and is reported on and discussed at the meetings of the General Assembly. Ninety-two such committees have been reported as working in the various international unions, their

activities covering a very wide field of knowledge. Each Union also appoints at its General Assembly a small Bureau of officers who are able to answer for the Union as a whole between meetings. Some of these have been badly broken up during the war years and are only now being rebuilt.

In addition to the International Unions there are in existence a number of International Congresses which meet from time to time in different countries but have no continuity of active existence between meetings. Broadly speaking it would be safe to say that those who have been actively concerned with these congresses and have pleasant recollections of their scientific discussions and fellowship do not desire to change them into international unions. The weakness of their position however is the lack of a body between meetings that can answer for the subject covered by the congress and that can nominate the most suitable members for co-operation with unions desiring their help. Borderline subjects needing international study are catered for by joint commissions between the various unions. It would be a help if an international congress would appoint a bureau to function between meetings to which the various requests for assistance or advice could be addressed. This is done in some cases already. In other cases union and congress both exist. The General Assembly of the Union meets at the same place as the Congress and within a day or two of the Congress meeting. Elasticity of organisation is desirable to meet the different needs and outlook of workers in different fields.

Joint commissions of the Unions have been active for over twenty years in some cases, for instance the joint commissions on latitude variation, on the determination of longitudes by wireless and on the Bureau de l'heure, in which both the Unions of Astronomy and of Geodesy and Geophysics are concerned. Some joint commissions are only planned as yet, e.g. a commission on Ionospheric Research which it is hoped to set up in due course with members from the Unions of Astronomy, Geodesy and Geophysics, Radio-Science and Physics. Other joint commissions proposed at the recent executive committee of the Council are on Oceanography (Biology and Geodesy and Geophysics), Physico-Chemical Constants (Physics and Chemistry), Viscosity (Chemistry, Biology, Geodesy and Geophysics). In the work of this committee it is hoped that means will be found to secure the co-operation of the International Congress of Applied Mechanics.

In addition to joint commissions between the Unions, which the Council may help to arrange, the Council also appoints committees of its own such as the Committee on Solar and Terrestrial Relationship, in which are members from the Unions of Astronomy and Geodesy and Geophysics. Another committee of the Council is one on Science and Social Relations (C.S.S.R.) appointed in 1937 to survey the most important results obtained and the directions of progress that are opening and of points of view brought forward in the physical, chemical and biological sciences with reference to their interconnection, the development of the scientific picture of the world and their practical application in the life of the community. In response to the inspiring and untiring energy of Prof. J. M. Burgers, Secretary of this committee, reports were being received from countries and unions in the years 1938–39 in readiness for collation and publication when the outbreak of war interrupted the work. Some of these reports, such as one on the Social Aspects of Science in Estonia, are now only of historical interest and the Committee has now been asked to prepare a survey of the published views of scientific bodies on the problems now arising in connection with researches into such matters as nuclear physics and drugs. Such a survey may enable the Council to make a reasoned

pronouncement, supported by the full weight of international science, on the ethical problems which face scientific men in particular to-day—thus accepting the challenge offered by Dr. Hill to the Executive Committee in his address of welcome at their recent meeting. A valuable contribution to the work of the C.S.S.R. will be provided by the annual reports on the work of the various Unions which the Council hopes to receive in future and to distribute widely.

The Council is linked by a convention to the International Organisation for Intellectual Co-operation of the League of Nations; the convention defines the separate spheres of action of the two bodies and the various ways in which each can help the other. While the fate of the International Organisation of the League of Nations is uncertain at present, there has come into existence the United Nations Educational Scientific and Cultural Organisation (U.N.E.S.C.O.). At the recent conference at which U.N.E.S.C.O. was formed a resolution was adopted, on the proposal of the delegation from the United States, asking the preparatory commission to invite its executive committee to examine with the International Council of Scientific Unions such methods of collaboration as might be practicable to strengthen the programmes of the two organisations within the limits of their joint concern; the Executive Committee of the Council has appointed a committee to consult with representatives of U.N.E.S.C.O. and it is hoped that much may arise from their discussion to the mutual advantages of both bodies. The clause introducing this resolution may well be taken as defining the task now facing the International Council of Scientific Unions:

"Il est urgent de reconstituer et de développer les moyens permettant aux savants de tous les pays d'échanger des renseignements et de travailler en commun au développement de la science et à son utilisation au service de l'humanité."

F. J. M. Stratton
General Secretary
International Council of Scientific Unions
Cambridge, England

BOOKS—WAR VICTIMS

During the war, the libraries of half the world were destroyed in the fires of battle and in the fires of hate and fanaticism. Where they were spared physical damage, they were impoverished by isolation. There is an urgent need—now—for the printed materials which are basic to the reconstruction of devastated areas and which can help to remove the intellectual blackout of Europe and the Orient.

There is need for a pooling of resources, for co-ordinated action in order that the devastated libraries of the world may be restocked as far as possible with needed American publications. The American Book Center for War Devastated Libraries, Inc. has come into being to meet this need. It is a program that is born of the combined interests of library and educational organizations, of government agencies, and of many other official and non-official bodies in the United States.

The American Book Center is collecting and is shipping abroad scholarly books and periodicals which will be useful in research and necessary in the physical, economic, social and industrial rehabilitation and reconstruction of Europe and the Far East.

The Center cannot purchase books and periodicals; it must depend upon gifts from individuals, institutions, and organizations. Each state will be organized to participate in the program through the leadership of a state chairman. Other chairmen

will organize interest in the principal subject fields. Co-operation with these leaders or direct individual contributions are welcomed.

WHAT IS NEEDED: Shipping facilities are precious and demand that all materials be carefully selected. Emphasis is placed upon publications issued during the past decade, upon scholarly books which are important contributions to their fields, upon periodicals (even incomplete volumes) of significance, upon fiction and non-fiction of distinction. All subjects—history, the social sciences, music, fine arts, literature, and especially the sciences and technologies—are wanted.

WHAT IS NOT NEEDED: Textbooks, out-dated monographs, recreational reading, books for children and young people, light fiction, materials of purely local interest, popular magazines such as *Time*, *Life*, *National Geographic*, etc., popular non-fiction of little enduring significance such as Gunther's *Inside Europe*, Haliburton's *Royal Road to Romance*, etc. Only carefully selected federal and local documents are needed, and donors are requested to write directly to the Center with regard to specific documents.

HOW TO SHIP: All shipments should be sent PREPAID via the cheapest means of transportation to THE AMERICAN BOOK CENTER, C/O THE LIBRARY OF CONGRESS, WASHINGTON 25, D. C. Although the Center hopes that donors will assume the costs of transportation of their materials to Washington, when this is not possible reimbursement will be made upon notification by card or letter of the amount due. THE CENTER CANNOT ACCEPT MATERIAL WHICH IS SENT COLLECT. Reimbursement cannot be made for packing or other charges beyond actual transportation. When possible, periodicals should be tied together by volume. It will be helpful if missing issues are noted on incomplete volumes.

K. R. SHAFFER,
Executive Director, American Book Center, Inc.
Library of Congress, Washington 25, D. C.

PUBLICATIONS RECEIVED

American Journal of Science, Vol. 244, No. 4 (April) and No. 5 (May), 1946, New Haven
"'High Potential' Areas in North America," by Ronald L. Ives (April).

Annales de Geophysique, Tome 2, Fasc. 1 (pages 1–96), 1946.
"Sur un Nouvel Abaque pour le Calcul de L'Influence de Couches Planes Magnetiques Minces," par V. Baranov, p. 25.
"La Methode Seismique de Prospection et la Recherche Scientifique Possibilites d'Application en France," par J. P. Rothé, p. 90.
"Note sur Certaines Formules de Geophysique Employees dans la Prospection Gravimetrique," par Pierre Charczenko, p. 93.

Bureau of Mines, I.C. 7349, Geophysical Abstracts 122, July–September, 1945 (May, 1946).

Cambridge Philosophical Society, Proceedings, Vol. 42, Part 1, February, 1946.

Economic Geology, Vol. XLI, No. 2 (March–April), 1946.

Geofisica Pura e Applicata, L'Istituto Geofisico Italiano, Milano, 1942–46.
Vol. IV, Fasc. 1–4, 1942:
"Caratteristiche dei sismogrammi di terremoti prossimi ad Atene (Grecia) e fenomeni relativi nella regione epicentrale," di N.A. Critikos, p. 82.
"La carta magnetica d'Italia della componente orizontale al 1940, o edita

recentemente dall' Istituto Geografico Militare," di Domenico Digiesi, p. 67.

"Gravimetria e prospezione della crosta terrestre," di Kurt Wegener, p. 1.

Vol. VI, Fasc. 1–4, 1943:

"La distribuzione del campo magnetico terrestre all'isola di Stromboli," di Mario Bossolasco, p. 11.

Vol. V "Determinazione di profondita ipocentrale effettuata col sussidio di un nuovo metodo energetico," di Emilio Perri, p. 47.

"L'Andamento della gravita' sui Mari," di Kurt Wegener, p. 107.

Vol. VI, Fasc. 1–4, 1944:

"Misure magnetiche in Albania," di Carlo Morelli, p. 14.

"Dodici anni di misure magnetiche in Italia dell' Istituto Geografico Militare," di Carlo Morelli, p. 13.

Vol. VII, Fasc. 1–4, 1945:

"Anomalie magnetiche e declinazione in quota in Italia con speciale riguardo per la navigazione aerea strumentale," di Carlo Morelli, p. 1.

Vol. VIII, Fasc. 1–2, 1946:

"Tettonica e sismicita' nella regione Albanese," di Mario Magnani, p. 1.

"Il terremoto delle prealpi Carniche dell's giugno 1934 e sua profondita' ipocentrale," di Giovanni Agamennone, p. 43.

Journal of Applied Physics, Vol. 17, No. 3 (March), No. 4 (April), and No. 5 (May), 1946.

Journal of the Institute of Petroleum, Vol. 32, No. 265 (January), No. 266 (February), and No. 267 (March), 1946.

Nafta ("Petroleum"), Petroleum Inst. of Poland, Krakow:

Rok. II, Nr. 1, January, 1946:

"Geophysical Research Program in the Carpathians and Foreland," by A. Kislow, p. 28.

Rok. II, Nr. 2, February, 1946:

"Underground Glowing of Oil Beds," by Henryk Gorka, p. 48.

Rok. II, Nr. 3, March, 1946:

"Tectonic Individuals of the Central Depression of Middle Carpathians and their Oil Accumulations," by J. Wdowizrz, p. 86.

Rok. II, Nr. 4, April, 1946:

"Electrical Coring," by A. Kislow, p. 146.

Quarterly Journal of the Geological Society of London, Vol. CI, Parts 1 and 2, Nos. 401–2 (Issued October 30, 1945) and Vol. CI, Parts 3 and 4, Nos. 403–4 (Issued February 28, 1946).

Review of Scientific Instruments, Vol. 17, No. 3 (March) and No. 4 (April), 1946.

Terrestrial Magnetism and Atmospheric Electricity, Vol. 51, No. 1 (March), 1946. "Diurnal Variations of the Radon-Content of Soil-Gas," by Edward M. Kovach.

World Petroleum, Vol. 17, No. 3 (March) and No. 4 (April), 1946. "Trends in Geophysical Exploration," by John F. Anderson. (March.) "Geophysical Activities in 1945," by C. A. Heiland (March).

REVIEW

In the past, the appearance of a review section in GEOPHYSICS has been irregular, as material for it has been submitted only occasionally. To make this section of greater interest and usefulness to the members, the Editor has formed a Committee which will provide review material regularly, the various members being assigned certain domestic and foreign periodicals which they will watch for articles of particular interest. The following have accepted appointment on this Committee:

T. A. ELKINS, Gulf Research & Development Company, Pittsburgh, Penna., *Chairman.*

R. A. GEYER, Humble Oil & Refining Company, Houston, Texas.

NORMAN RICKER, Carter Oil Company, Tulsa, Okla.

D. C. SKEELS, Standard Oil Company of New Jersey, New York, N. Y.

J. F. Enslin. *A comparison of the gravimeter and torsion balance methods of geophysical prospecting.* Transactions of the Geological Society of South Africa, 47, 283–299 (1944).

This comparison is of interest especially to geophysicists in the United States because it is based on experience in the Union of South Africa and yet confirms the usually accepted practice here of using gravimeter surveys in preference to torsion balance surveys.

The basic principles and methods of use of the torsion balance and the gravimeter are briefly sketched to indicate the factors which determine the limiting accuracy of each instrument. For the torsion balance the probable error depends mostly on the accuracy with which the terrain corrections are made. As is usual, the curvature values are ignored. The author states that under very favorable conditions, as over sedimentary formations, the probable error of the gradient is at least 5 E°, while under less favorable conditions, as on dolomite and igneous formations, the probable error may be greater than 50 E°, but an average error of 20 E° is used for such conditions in the further discussion. For the gravimeter, the instrumental drift is of fundamental importance; the author states that he has made readings with an accuracy of 0.02 mg. for stations taken at 20-meter spacing, and 0.1 mg. for stations at 1,000-meter spacing.

To compare the two methods, anomalies typical for the Union of South Africa are studied from theoretically computed curves of gravity and gradient. As a basis of comparison is used the ratio between the values of the gradient (or gravity difference) and its probable error, which is called the *accuracy ratio.* The values of gradient (or gravity difference) used are typical values such as the maximum value or the change over a distance equal to the station spacing. Two types of problems are distinguished: small-scale, such as the location of ore veins or thin dykes; and large-scale, such as the location of a fault of 1,000 foot throw, under a sedimentary cover. For small-scale problems the accuracy ratio for the anomalies studied is the same for both instruments; for large-scale problems the accuracy ratio for the gravimeter is five to ten times that for the torsion balance.

Finally the factors of cost and speed are considered. The author states that the cost of running a torsion balance party (two or three instruments) is about the same as the cost of running a gravimeter party (one instrument) but that the gravimeter party can observe two to five times the number of stations per day; while for large-scale problems the number of gravimeter stations needed is only one-fifth the number of torsion balance stations. He concludes thus that gravimeter surveys are to be preferred.

T. A. ELKINS

CONTRIBUTORS

WILLIAM C. WOOLLEY

WILLIAM C. WOOLLEY received the degree of A.B. in Physics from the University of California at Los Angeles in 1934, thereafter completing a year of graduate work in Physics at the same university.

From 1935 to 1938 he was employed by the Rieber Laboratory, a contract seismograph company operating in California and Texas. Since 1938 he has been engaged in seismograph exploration work with Magnolia Petroleum Company. He is a member of the Dallas Geological Society and of the Society of Exploration Geophysicists.

A. P. WENDLER completed his undergraduate work in geology and received his B.A. degree from the University of Texas in 1929. He worked for the Gulf Production Company as a surface geologist in the Gulf Coast of Texas from June of 1929 to January of 1931. In March of that year he was employed by the Ramsey Petroleum Company as a surface and subsurface geologist. From September 1931 to June 1934 he did graduate work in sedimentation at the University of Texas, receiving his M.A. degree in 1932 and his Ph.D. degree in 1934. Since June 1934 he has been a seismic computor for the Humble Oil and Refining Company of Houston, Texas.

A. P. WENDLER

DR. SYLVAIN J. PIRSON

Dr. Sylvain J. Pirson received a degree of Mining Civil Engineer in 1929 from the University of Louvain, Belgium, following which he was awarded a C. R. B. Educational Fellowship for the purpose of studying petroleum geology at the University of Pittsburgh, Pittsburgh, Pennsylvania, where he received the degree of Master of Science in 1930. Under a renewal of the fellowship he studied geophysics at the Colorado School of Mines, Golden, Colorado, where he received the degree of Doctor of Science in 1931. He further studied electronics in Hannover, Germany and at the University of Louvain before returning to the U. S. A. as an instructor in geophysics at the Colorado School of Mines in 1933. In 1934, he joined the Seismograph Service Corporation of Tulsa, Oklahoma as geophysicist and in 1936, the Gulf Research and Development Corporation in Pittsburgh. Later on in the same year he was appointed Professor of Petroleum and Natural Gas Engineering at the Pennsylvania State College where he also teaches geophysical exploration.

He is the author of some forty papers dealing with the field of geology, geophysics, petroleum and reservoir engineering, education and petroleum economics.

He is active as a consultant particularly in the fields of geochemical and electrical prospecting and in magnetic and gravimetric interpretation.

He is a member of A.I.M.E.; A.A.P.G.; Amer. Geophys. Union; Pgh. Geol. Soc.; A.A.A.S.; Sigma Xi and of the Society of Exploration Geophysicists.

GARY MUFFLY

Gary Muffly received a B.S. degree in Electrical Engineering from the University of Michigan in 1932. Since 1933 he has been employed by the Gulf Research and Development Company in geophysical work. From 1933 to 1935 he operated a pendulum gravity instrument on the Gulf Coast. Since 1935 he has done development and patent work on radio, seismograph, and other types of apparatus. He is a member of the Society of Exploration Geophysicists, Tau Beta Pi, and Phi Kappa Phi. He is an associate of the Institute of Radio Engineers and Sigma Xi.

JAMES TAYLOR

JAMES TAYLOR obtained the Degrees of B.Sc. in Physics with 1st Class Honours, and Ph.D. at the University of Durham. After a period of work in the Duc de Broglie's Laboratory in Paris, he studied at the Physical Institute of the University of Utrecht, Holland, obtaining the Degree of Doctor of Physics and Mathematics cum laude. Thereafter he worked in the Cavendish Laboratory, Cambridge, England, until in 1928 he joined the Research Department of Imperial Chemical Industries Limited, Explosives Division. In 1930 he obtained the Degree of Doctor of Science for investigations on the Electrical Discharge through Gases. He has since worked on a wide range of problems on Explosives, and is now Associate Research Manager and Research Manager designate of the Research Department of Imperial Chemical Industries Limited, Explosives Division, in Scotland.

GEORGE MORRIS obtained the Degree of B.Sc. with 1st Class Honours at the University of London in 1924 and was awarded the Carey Foster Research Prize in Physics by University College London in 1925. In that year he joined the Research Department of Imperial Chemical Industries, Limited, and he is now in charge of the Physics Laboratory of the Explosives Division. Mr. Morris is a Fellow of the Physical Society.

GEORGE MORRIS

T. C. RICHARDS obtained the degrees of B.Sc. in 1926 and Ph.D. in 1934 from London University. He was head of the Physics Department, Rotherham Technical College from 1932 to 1935. Since 1935, he has been with the Anglo-Iranian Oil Co., Ltd., where he has supervised magnetic, gravity, and seismic refraction and reflection work in England, Iran, India, Burma, and now in the Bahamas. He has published papers on optics, thermal expansion, and the elasticity of rocks.

He is an Associate of the Royal College of Science, a Fellow of the Institute of Physics, and a member of the Society of Exploration Geophysicists.

T. C. RICHARDS

G. J. BAKER

G. J. BAKER received the B.A. and M.A. degrees in geology from the University of Wisconsin in 1927 and 1932, and studied mathematics and geophysics at Massachusetts Institute of Technology during 1932–34. He was in Africa four years as a geologist in Northern Rhodesia and the Gold Coast. He became engaged in commercial geophysics in 1935 when he was employed by Schlumberger Well Surveying Corporation of Houston, Texas. Since 1938 he has been with William M. Barret, Inc., and is currently engaged in theoretical research. He is a member of A. I. M. E.

MEMORIAL

THE WAR AND THE SOCIETY OF EXPLORATION GEOPHYSICISTS

A EULOGY*

It is fitting that we pause for a few moments to recall the services of the members of the Society of Exploration Geophysicists to their country during the war and to commemorate for a brief moment the gold stars among our members who gave their lives for their country.

While we do not have a complete or detailed record of the part played by our members in war research or of all of those who served in the armed forces, or of those who suffered wounds or other injuries in service, the record, incomplete as it is, is very impressive. I am indebted to our efficient business manager, Miss E. Stiles, for the following figures.

At least 117 of our members are known to have served in the war;—74 in the American Army and one in the British Army; 37 in the American Navy and one in the Canadian Navy; two in the Marines and two in the Coast Guard. The known casualties among these, all in the United States Army, were four.

In addition to those who served in the armed forces, 25 of our members were engaged in the Naval Ordnance Laboratory in Washington. Seven had a part in the work of the Applied Physics Laboratory at Johns Hopkins University. Seven were on the staff of the Radiation Laboratory at Massachusetts Institute of Technology. Three were in the Underwater Sound Laboratory; four in the Radiation and Sound Laboratories of the Navy and Signal Corps; and two were assigned to the Woods Hole Oceanographic Laboratory. Twelve others took part in the work of Government war bureaus or in training schools.

It will be of interest to note that out of the total of 117 in the armed forces 104 were officers. Their ranks according to Miss Stiles were Ensign, 6; Lieutenant (jg), 8; Lieutenant, 31; Captain, 26; Lieutenant Commander, 6; Major, 18; and Lieutenant Colonel, 9.

An excellent report on the part taken by geophysicists in the war effort was published by Doctor C. A. Heiland in *Mining and Metallurgy*, Annual Review Issue.

Dr. Heiland mentioned especially the contribution of geophysicists to the various types of radar, loran and shoran, to the proximity fuse, the atomic bomb, to sound ranging and sonar, to acoustic bomb scoring, to magnetic mine defense, to land mine detection, to aerial magnetic mapping, to aircraft testing and development, and to the location of hurricanes and other storms by means of microseisms.

The four members of our Society who lost their lives in the war and whom, in a special way, we wish to commemorate are:

Major J. G. Kearby, of the Equipment Laboratory at Wright Field, who was instantly killed in an airplane crash in 1943.

Major John Murio Golden, of the 1265th Engineers Combat Battalion, who was killed in a car wreck in Germany in 1945.

Lieutenant Reed L. McCartney, of the 23rd Infantry who was sent to Manila, November 1941, was captured by the Japanese, and was killed on board a Japanese prison ship which was torpedoed in the Pacific.

Lieutenant Billy E. Richard, of the Army Air Corps, who was killed on active duty over New Guinea in 1945.

In grateful memory we honor their heroism; and we hope that their supreme sacrifice for preservation of our free American institutions will not have been made in vain.

* Read at the Chicagomeeting of the Society by Father J. B. Macelwane.

THE SOCIETY ROUND TABLE

APPLICATIONS FOR MEMBERSHIP APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following candidates for membership in the Society. This publication does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it to the Secretary within thirty days. (Names of sponsors are placed beneath the name of each nominee.)

ACTIVE

Armstrong, Lee C.
Joseph A. Sharpe, G. A. Foster, J. C. Rollins

Babb, John Joseph
Cecil H. Green, H. B. Peacock, Eugene McDermott

Bertolet, Edward Calvin
Walter A. English, Frank Ittner, Cecil E. Reel

Blundun, George John
L. J. Peters, L. W. Gardner, E. A. Eckhardt

Bychok, Victor
A. E. McKay, Howard L. Cobb, C. H. Hightower

Clark, William White
Geo. E. Wagoner, Henry W. Brown, Paul L. Lyons

Clifford, Oliver Charles, Jr.
Cecil H. Green, A. E. McKay, Howard Cobb

Cook, Kenneth Lorimer
J. H. Swartz, Milton B. Dobrin, Art. III-D-1 of Constitution

Couch, Robert Garwood
A. P. Crary, Robert H. Mansfield, J. R. Maxey

Donohoo, Horrie Van Waldo
C. A. Heiland, Wm. S. Levings, A. J. Hintze

Dunaway, James Howard
W. M. Rust, Jr., D. H. Gardner, W. D. Mounce

Dundon, Robert Frederick
Cecil H. Green, Phil P. Gaby, Francis A. Hale

Enslin, Johan Frederik
(Art. III-D-1 of the Constitution)

Feagin, Frank Joe
W. M. Rust, Jr., Derry H. Gardner, D. P. Carlton

Fuller, Oscar Kenneth
C. Hewitt Dix, Herbert Hoover, Jr., Berthold W. Sorge

Galloway, John Otis
Eugene McDermott, J. W. Hoover, Cecil H. Green

Gemmill, Edward J.
W. Harlan Taylor, August F. Beck, R. M. Bradley

Guimarães, Helio Pentagna
Decio Saverio Oddone, Wayne H. Denning, Martin Eichelberger, Jr.
Hathaway, Milton Sisson
C. J. C. Harvey, L. C. Spencer, J. A. Gillin
Hendrson, Bill
Hugh C. Schaeffer, John L. Bible, Neal Clayton
Hill, Edwin Bruce
W. M. Rust, Jr., D. H. Gardner, W. D. Mounce
Hill, Robert Grant
Geo. H. Speirs, John W. Marston, Keith H. Odenweller
Johnson, Frank Burton
W. M. Rust, Jr., Marion A. Arthur, M. C. Terry
Locke, Edgar Rice
Roy L. Lay, C. R. Wallace, L. A. Scholl, Jr.
Long, Clarence J.
K. E. Burg, Karl Dyk, Paul D. Balbin
Maree, Burgert Daniel
(Art. III-D-1 of the Constitution)
Martin, Jack
Irving M. Griffin, Jr., Chester Sappington, T. O. Hall
McLoad, Kenneth Wehrli
Paul E. Nash, Geo. E. Conover, Henry C. Cortes
Morehead, Jack Nathaniel
Sidon Harris, Paul Ledyard, Howard Itten
Nalley, Leonard L.
H. Salvatori, Dean Walling, John C. Mollere
Neese, Urban Earl
John L. Bible, Robert H. Ray, Carl L. Larson
Nery, Raymundo Carlos
Decio Saverio Oddone, Wayne H. Denning, Martin Eichelberger, Jr.
Pearson, Harry
A. van Weelden, T. A. van Melle, K. A. Weatherburn
Pugh, William Emerson
A. J. Hintze, A. J. Barthelmes, T. A. Manhart
Ruska, Walter Ernest Adelbert
H. B. Peacock, Wm. M. Rust, Jr., F. Goldstone
Scharon, Harry LeRoy
J. H. Swartz, Art. III-D-1 of the Constitution
Stafford, Clare Jones
John L. Bible, Hugh C. Schaeffer, Elliott Sweet
Starr, A. G.
G. P. Montgomery, G. L. Jackson, R. S. Duty, Jr.
Sweet, Reginald Cooper
H. C. Schaeffer, E. V. McCollum, Craig Ferris
Tilley, Aubra Everett
J. E. Bondurant, C. L. Brownlow, W. H. Courtier
Totten, Stanley W.
Neal J. Smith, E. T. Nichols, James H. Todd
Waggoner, James Woodrow

Tom D. Mayes, Thomas J. Bevan, Jack W. Peters
Walker, James Ryan
E. L. Caster, B. B. Burroughs, John E. Taylor
Webster, Felix Howard
John E. McDougall, R. N. Bills, Richard Williams
Wise, Jack Beauregard
M. P. Jones, J. W. Horn, R. F. Gore
Wright, Ray Harroun
Cecil H. Green, Ewin D. Gaby, M. C. Kelsey

ASSOCIATE

Courtney, Chyde Jasper
N. J. Smith, J. H. Todd, L. I. Brown
Creighton, Roger Blake
N. J. Smith, J. H. Todd, L. I. Brown
Harris, Phil Clarence
John L. Bible, Hugh C. Schaeffer, Glenn M. McGuckin
Jackson, Charles Kenneth
C. M. Ross, F. W. Borman, Andrew Gilmour
Johnson, Joseph Carey
Norman Ricker, Geo. E. Wagoner, Henry W. Brown
Kelsch, Raymond Lester
C. E. Reel, Frank Ittner, L. B. Trombla
McDonald, William Charles
J. R. Maxey, Robert H. Mansfield, A. P. Crary
Patterson, Arleigh Ray
A. P. Crary, Robert H. Mansfield, J. R. Maxy
Tilleux, Harry Oscar
L. I. Freeman, C. D. Keen, Wm. M. Wells
Wise, Richard Atlee
Rex White, A. J. Z. Caan, H. R. Moorman

TRANSFER FROM ASSOCIATE TO ACTIVE

Ballard, James A.
Meador, Bernal M.
Moore, Joe Hiram
Myers, Charles E.
Robinson, John L., Jr.
Woolson, John R.

RE-INSTATEMENT

Charscke, Charles J.

RESIGNATION

Carson, J. P. (Change of occupation)

Meeting of Executive Committee, North Ball Room, Stevens Hotel, Chicago, Tuesday Afternoon, April 2, 1946

Session of the Society of Exploration Geophysicists, North Ball Room, Stevens Hotel, Chicago, Tuesday Afternoon, April 2, 1946

SIXTEENTH ANNUAL MEETING OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS

The sixteenth annual meeting of the society was held at the Stevens Hotel, Chicago, in conjunction with the thirty-first annual meeting of the American Association of Petroleum Geologists and the twentieth annual meeting of the Society of Economic Paleontologists and Mineralogists.

The technical sessions of the Society of Exploration Geophysicists were held on Monday, April 1, morning and afternoon and Tuesday afternoon, April 2. The Annual Business Meeting of the society was held on Monday morning, April 1; the minutes of this meeting are included in the Secretary's report, page 426.

Particular attention in arranging the program was given to Case History papers and the Monday afternoon session consisted entirely of such papers. The particular interest in this subject at the present time is occasioned by the decision of the Business Committee of the society to publish a volume of case histories. This volume and the reasons for it were the subject of the Presidential Address by the retiring president, Henry C. Cortes, which is published as the first paper of this number of GEOPHYSICS.

The success of the meeting is due in very large part to the efforts of the Program and Arrangements Committees, the members of which are listed in the January, 1946 number, page 109.

HOUSTON REGIONAL MEETING OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS

The Society of Exploration Geophysicists held a one day regional meeting on Thursday, April 25, 1946, in the Ballroom of the San Jacinto Hotel, Houston, Texas. Approximately 300 geophysicists and geologists attended this meeting, at which twelve technical papers were presented on various subjects of interest to the industry.

Mr. Henry Cortes, retiring President, stressed the importance of publishing case history papers and the benefits to be derived therefrom. He requested the cooperation of all companies in submitting additional manuscripts in order to permit the publishing of a complete volume of case history papers by the Geophysical Society during the current year.

Dr. J. J. Jakosky, incoming President of the Society, was unable to be present at this meeting, but Mr. Cecil Green, newly elected Vice-President, attended and stated that in view of the considerable interest shown in this year's regional meeting, serious consideration would be given toward holding another such meeting next year in either Houston, Dallas, Fort Worth or Tulsa.

PAPERS PRESENTED OR READ BY TITLE AT THE TECHNICAL SESSIONS OF THE SIXTEENTH ANNUAL MEETING

1. S.E.G. Presidential Address—Geophysical Case Histories. Vol. 1.

   Henry C. Cortes, Magnolia Petroleum Company, Dallas, Texas.
   (Read by Mr. Cortes at Chicago and Houston)

2. WILLIAM B. HEROY, Director of Foreign Production, Petroleum Administration for War, Washington, D. C.

   Foreign Geophysical Activities in 1945.

   Information received by the Petroleum Administration for War from operators

in foreign countries shows that there was an increase of about 25 per cent in the number of geophysical parties in the field during the first half of 1945 as compared with the last half of 1944. Altogether, 74 parties were reported as operating during the first half of the year, of which 45 were using seismic and 20 gravimetric methods. Forty-seven parties were in the Caribbean area, 16 in Mexico, Central America and the West Indies, 8 in other countries of South America, and 3 in the Eastern Hemisphere. No figures are available for the second half of 1945 as reports were discontinued.

3. PAUL F. HAWLEY, Consolidated Engineering Corporation.

Geophysical Contributions to Vibration Measurements and Micro-Chemistry.

(Read by Mr. Hawley at Chicago)

Sensitive and compact vibration recording equipment was evolved from seismic geophysical equipment, under war-time needs for measuring vibration and strain in aircraft. Peace-time uses in aircraft, railroad, and automotive testing are increasing.

Equipment involves one of the two types of systems:

(a) Velocity of displacement recording, using miniature low frequency seismometers, flat or integrating amplifiers, and a multi-channel recording oscillograph;

(b) Acceleration or strain recording, using accelerometers or resistance wire strain gauges in multiple a.c. bridges, carrier amplifiers with phase-sensitive domodulators, and oscillographs.

The mass spectrometer as a micro-analytical apparatus was developed for geochemical applications. It was subsequently adapted to analysis of light hydrocarbon refinery streams and as such has been installed at most major refineries. Analysis is rapid and accurate.

4. IRWIN ROMAN.

An Observational Method to Overcome Zero Drift Error in Field Instruments.

(Read by Dr. Roman at Chicago)

By using a four-step oscillating method of observation, four values are obtained for the increment in the measured value between consecutive stations. If the drift or "zero creep" of the instrument is regular, even when large, or not linear, this furnishes a means of improving the reliability of the readings and permits the detection of erratic readings. In areal surveys, a primary net of values may be established by this oscillating method and this net used as a base into which to adjust chains of observations. Intermediate values may sometimes be desirable, such values being adjusted into the primary net by the oscillating method. An example shows the application of the method to a gravimetric survey.

5. F. J. WILLIAMS, Geophysical Service, Inc.

Notes on Shot-Point Procedure.

(Read by Mr. Williams at Chicago and Houston)

Some characteristics of seismic explosives are reviewed, and an attempt is made to outline optimum shot point procedure from the standpoint of efficiency

and quality of data. Care in preparation of charges is stressed, with special emphasis on cap placement and charge assembly.

The time-current relations of a specific seismic cap are given, and the effect of the resistance of the firing circuit upon detonation time is discussed.

Suggestions are made in regard to the choice of the most favorable location for the up-hole time seismometer.

It is concluded that adherence to well defined specific shot point procedures is essential to the efficient procurement of highest quality recordings.

6. D. H. WEINSTEIN, Assistant Chief Geophysicist, Superior Oil Company.

Optics of Recording Oscillographs.

(Read by Mr. Weinstein at Chicago and Houston)

The results of A. C. Hardy are applied to show how one can favorably influence the size and shape of a galvanometer mirror to either increase the illumination, or decrease the moment of inertia of the mirror without loss of illumination. This applies only to cylindrical systems.

It is based on the fact that for maximum illumination, the cylindrical lens in front of the recording paper is focused on the galvanometer mirror. Therefore the galvanometer mirror does not act as a stop in the vertical direction. Consequently, the illumination of the galvanometer spot is independent of the mirror height. In other words, the illumination is not proportional to the area the galvanometer mirror, but depends only on the mirror width.

However, the height of the galvanometer spot on the paper is reduced with reduction in mirror height, so that it is necessary to compensate for this by increasing the focal length of the cylindrical lens. The limitations of this procedure are gone into. The bearing of the above on timing line intensities is also discussed.

The factors bearing on the illumination of the galvanometer spot on the recording paper of an oscillographic camera are presented. It is shown how one can increase the illumination for a given moment of inertia of the galvanometer mirror, or the illumination maintained with a decrease in the moment of inertia.

7. EUGENE FROWE, Chief Physicist, Robert H. Ray Company.

A Diving Bell for Underwater Gravimeter Operation.

(Read by Mr. Frowe at Chicago and Houston)

The recent development of a diving bell, designed to carry a gravimeter and observer, enables the geophysicist to make correct gravity observations on a river, river, lake or ocean floor. The bell, for which patents have been applied, is designed to operate in depths of water as great as 250 feet. It has been used with good results at depths ranging from 8 to 70 feet.

Data taken from adjacent land and sea areas have been contoured and the smoothness of the resulting contours indicates that the underwater gravity readings are entirely reliable.

Structural features of the diving bell and related equipment are described and plates showing exterior and interior views of the bell are given.

8. DARWIN S. RENNER, Superintendent of Electronics Division, Geophysical Service, Inc.

Seismometer Engineering.

(Read by Mr. Renner at Chicago)

Theory of design, as illustrated by the dynamic and reluctance types, is started with differential equations. It is carried from there to the equivalent circuits. Next response parameters Q and W are introduced and optimum designs considered with these given. Optimum relations involving actual design parameters are finally evolved.

9. FRANK RIEBER, Rieber Research Laboratory.

Uses of the Vibroton in Geophysics.

(Read by Mr. Rieber at Chicago)

The Vibroton is a continuously and sharply tunable mechanical resonant system. Used as the controlled element in an oscillator, it provides a compact and precise time standard and can be used in place of a tuning fork. As a means for translating minute displacements into changes in frequency, it may be used for a large number of applications where quantities measured in one place are to be registered or indicated at a distant place. Applications to refraction seismography, to barometric leveling, and to the measurement of pressures and temperatures in bore holes, will be discussed.

10. L. W. GARDNER, Gulf Research and Development Company.

Vertical Velocities From Reflection Shooting.

(Read by Mr. Gardner at Chicago and J. E. McGee at Houston)

A method of determining vertical velocities from reflection shooting is described in which a special array of spreads is used by which: (1) surface corrections are cancelled or minimized and (2) common center points for pairs of long and short set-ups are used to minimize errors in the determination of angularity corrections. Examples are given in which velocities determined by this method are compared with those obtained from well shooting.

11. G. L. BEYER, JR. AND WARD SHEPPARD, JR., Naval Ordnance Laboratory, Washington, D. C. Sponsored by Milton B. Dobrin.

A Recording Six-Trace Cathode Ray Oscillograph.

(Read by Mr. Beyer at Chicago)

A portable, general purpose six-trace cathode ray oscillograph is described. Eight 2-inch cathode ray tubes are arranged side by side in a line. Six of these tubes have individual d-c amplifiers which have high gain, high input impedance, good high-frequency response, and excellent stability. The two outside cathode ray tubes give calibrated timing pulses.

A built-in camera with a fast lens photographs the cathode ray tubes on standard 35 mm. film, to give a continuous time-displacement recording of the cathode ray spots. The film may be driven past the lens aperture at speeds continuously variable from a few inches per second to 15 feet per second. A 100-foot film supply system can be used, or a 10-inch strip can be fastened around the drive drum for short records.

Film can be processed rapidly, and readily examined with a viewer having a 5- to 10-diameter magnification. More complete analysis of records can be made from enlargements.

12. WALTER J. OSTERHOUDT, Supervisor of Geophysical Operations, Houston Division, Gulf Research and Development Company.

The Seismograph Discovery of an Ancient Mississippi River Channel.
(Read by Mr. Osterhoudt at Chicago and Houston)

In January, 1937, Gulf Research and Development Company's Seismic Party 14 began reflection and refraction seismograph surveys of south Timbalier Bay, Lafourche Parish, Louisiana, and adjacent waters of the Gulf of Mexico in the vicinity of 29° 05′ N. latitude, 90° 15′ W. longitude. Experimental shooting to determine the thickness of the slow-velocity zone revealed exceptional local variations in depth to a fairly consistent V_2 underlier. Using a measured velocity of 3,800 feet per second for the recent fill-in material, cross-section profiles were plotted carefully, and sufficient data were acquired to outline the east flank of a buried river channel, probably over 600 feet deep and perhaps more than 5 miles wide. It was assumed by the author that only a more youthful and powerful Mississippi River could have created such a deep channel with steep valley walls. In subsequent years this remarkable channel has been found at three places between the Gulf of Mexico and the vicinity of Houma, Louisiana, by G. R. & D. C. seismograph parties.

The buried channel discovered by the seismograph possesses the approximate dimensions and characteristics exhibited by the portion of a submarine valley mapped by the United States Coast and Geodetic Survey in the Gulf of Mexico from 28° 14′ N., 89° 27′ W. through 28° 38′ N., 89° 57′ W.

Further exploration of the buried Mississippi channel by seismograph methods, core holes, and electronic logging of shallow holes is discussed.

13. WILLIAM C. WOOLLEY, Magnolia Petroleum Company.

Geophysical History of the La Gloria Field, Jim Wells and Brooks Counties, Texas.
(Read by Mr. Woolley at Chicago and Houston)

This paper presents a historical record of the Geophysical activity in the area of the La Gloria field.

The successive stages of geophysical exploration were:

1. Torsion balance.
   a. Magnolia Petroleum Company Crew, 1934–1935.
2. Seismograph.
   a. Correlation reflection seismograph—Independent Exploration Company Crew, 1936.
   b. Dip reflection seismograph—Magnolia Petroleum Company Crew, 1938.
   c. Correlation reflection seismograph—Magnolia Petroleum Company Crew, 1938.
3. Gravity survey.
   a. Coastal Oil Finding Company Crew, 1945.

The discovery well, Magnolia's Sam Maun No. 1, was drilled and completed in 1938–1939, producing initially 165 barrels per day of 65° gravity distillate and 5,646,000 cubic feet of gas through a 5/16-inch choke.

Oil and gas in the La Gloria field are being produced from sands in the Frio formation of Oligocene age. There are a number of sands producing gas distillate. Several flank wells produce oil. The field has been unitized and a recycling plant is engaged in processing the gas distillate.

14. HOLLAND C. MCCARVER, Chief Geophysicist, Seaboard Oil Company of Delaware.
LLOYD G. WEST, District Geologist, Seaboard Oil Company of Delaware.
(Read at Chicago and Houston)

The Geology and Geophysics of the Odem Oil Field, San Patricio County, Texas.

This paper discusses the successive steps in geological and geophysical exploration that led to the discovery of the Odem oil field. The original seismograph maps are presented, showing the discovery of structure in an area apparently condemned by dry holes. The remarkably close relationship of seismograph structure to areas subsequently proven productive is illustrated. A geological structure map is presented; also a cross-section comparing seismic and well data.

15. A. P. WENDLER, Seismic Computor, Humble Oil and Refining Company.
A Geophysical History of the Lovell Lake Oil Field, Jefferson County, Texas.
(Read by Mr. Wendler at Chicago and Houston)

Before the advent of geophysics the proximity of Spindle Top to the Lovell Lake area, peculiar topography, and rumored gas seeps prompted the drilling of a number of wells. In 1929 a torsion-balance minimum roughtly delineated the present area of the field. Later this minimum was checked by the gravity meter. In 1933 and again in 1935 reflection-seismograph surveys pointed to this locality. Shortly after the discovery well was brought in a final reflection-seismograph survey defined the Lovell Lake Structure rather accurately.

16. L. L. NETTLETON, Gulf Research and Development Company.
Geophysical History of Typical Mississippi Salt Domes.
(Read by Dr. Nettleton at Chicago and W. B. Lee at Houston)

This paper gives the results of gravity and seismograph exploration of typical shallow domes in the Mississippi salt-dome basin. The domes were first indicated by reconnaissance gravity surveys and were further defined by detailed gravity surveys. Depth and configuration of the cap rocks were determined by refraction-seismograph surveys. The geophysical predictions are compared with the findings of subsequent drilling.

17. STUART W. SEELEY, Radio Corporation of America.
Shoran Precision Radar.
(Read by Mr. Seeley at Chicago)

18. J. BRIAN EBY, Consulting Geologist, Houston, Texas.
The Status of Geophysics.
(Read by Dr. Eby at Chicago)

Geophysical exploration has enjoyed a steady and successful advance from its introduction in this country in 1923 to the present time. It was during the first decade that the exploration program was divided nearly equally between the larger oil companies and the larger independent geophysical organizations.

During the second decade, from 1933 to 1943, there was a very pronounced tendency for an increasing subdivision of the largest geophysical organizations into many small independent exploration companies. This tendency for experienced geophysicists to branch off from the larger oil company staffs and the larger geophysical organizations to form their own companies existed up until about a year or so ago. At the present time, there is, in the writer's opinion, a need for more consolidation of geophysical thinking and organization rather than increased breaking apart into smaller and smaller exploratory units. The time has come where more and more cooperation is urgently needed to advance the science as a whole.

The cost of research, the application of new instruments and new methods are almost beyond the research of the small one to four party organizations. These matters should be kept in mind not only by the smaller geophysical units now existing, but those who contemplate entering this field. Some way should be devised whereby the smaller, substantial, operating geophysical organizations have a better opportunity of sharing in progressive research methods and equipment. If mistakes are made by the smaller organizations as a result of a lack of this contact, the damage done affects adversely not only the organization involved but the entire science of applied geophysics as well.

19. D. C. SKEELS, Research Geophysicist, Standard Oil Development Company.

Ambiguity in Gravity Interpretation.

(Read by Dr. Skeels at Chicago)

Examples are given of alternative solutions of gravity anomalies, which support the thesis that no unique solution is possible without additional data other than gravity, and that the range of possible solutions, in terms of depths and shape of the geologic structure, may be very large.

20. E. E. ROSAIRE, Subterrex.

General Consideration for the Premium Technological Discovery of Petroleum.

(Read by Dr. L. W. Blau at Chicago and Dr. Rosaire at Houston)

Premium technological discovery volume is that achieved in excess of the volume to be anticipated on the basis of price alone and which can be attributed solely to technological advance.

Three degrees of freedom, area, method, and objective, are recognized for the prospector, and these are fixed by choice in any prospecting venture. Continued operation with these three degrees fixed leads inevitably to diminishing returns and, finally, to marginal operations wherein price becomes the primary motivation.

Under such conditions in the past, unfixing even one degree of freedom often has led to marked increases in the rate of discovery, i.e., to premium technological discovery. Such discovery surges have occurred more than once in the same petroleum province and, not infrequently, the magnitude of the surges has increased rather than decreased with time.

Considerations are presented for a return to premium technological discovery within the United States. Thus, for the method now in most general use, the reflection seismograph, such a return can be expected to follow from unfixing the area degree of freedom through initiating prospecting along the continental shelf. However, for prospecting as a whole such a return, and probably of even greater magnitude, can be anticipated to follow from unfixing the method degree of freedom through widespread application of novelty in prospecting methods.

21. C. HEWITT DIX, Vice-President, United Geophysical Company.

Efficiency in Exploration. I. General.

(Read by Mr. Dix at Chicago)

We use the word *efficiency* in the present context to mean "the value of the found oil divided by the cost of finding" or "the value of what is found per dollar of finding cost." Before the oil is found, we can evaluate each step. At each stage we use the *expected efficiency* which is "*the expected* value at the given date per dollar finding cost to date." The "expected value" is "the probability of finding oil times the value of the oil to be found." Obviously "the value of the oil to be found" can be known only after it is found. However, the expected efficiency is of value insofar as it serves to evaluate alternative exploration process since it does give relative values, making the selection of a most efficient process possible. "Probability of finding" is based on information to date including previous experience of people making the evaluation of this probability. Its value is one for certainty of success and zero for certainty of failure. It is intermediate between zero and one for intermediate situations. The estimate of probability is rough at first but becomes more and more accurate as more and more experience is accounted for by the present process.

22. SYLVAIN J. PIRSON, Pennsylvania State College.

Disturbing Factors in Geochemical Prospecting.

(Read by Dr. Pirson at Chicago)

A review of the results of over 3,000 measurements of soil ethane emanation rate made over the past five years has revealed a number of conclusions which have an important bearing upon the validity of geochemical methods of prospecting for oil and gas fields. A number of factors have been found to be highly disturbing, namely: earth topography, ground water percolation and seepage, barometric pressure variations, etc. These effects result in fluctuations of the rate of escape of hydrocarbon accompanied by horizontal shifts of leakage which give rise to the creation of artificial leakage highs altogether meaningless from the point of view on oil and gas accumulation at depth. Certain qualitative rules of interpretation have been established which permit weeding out the meaningless anomalies provided sufficient information is at hand on the topography and watertable movement.

A further observation has been made indicating that the artificial anomalies are often of greater magnitude than the significant measurements. Hence the problems, so common in other geophysical methods, of making important reductions on the observed figures is imperiously facing the exploration geochemist if he is to develop a valuable prospecting tool. A serious attempt is presently made to solve this problem.

23. LEONARD J. NEUMAN, Consulting Engineer, Houston, Texas.

Multiple Refraction Shooting in Southern Florida.

(Read by Mr. Neuman at Chicago)

In the multiple refraction method the first arrival energy of several refracted events are recorded on a single oscillogram. Each of the refracted events usually possess sufficient character to enable the interpreter to correlate these events for

many miles in southern Florida. The subsurface can be profiled continuously. Such refracted events were recorded from several Limestones and the Crystalline Dolomite. This procedure enables one to determine the velocities, depth, intervals and dips of these geological horizons. The use of nth order refractions would enable one to determine velocities and dips but not to accurately determine the depths and intervals. Velocities of the formations down to 2,000 feet or more, are very variable in southern Florida. This precludes the possibility of using the ordinary reflection method with any great accuracy, even though reflections may be recorded.

24. H. L. SCHIFLETT, Manager, States Exploration Company.

Quantitative Interpretation of Gravimetric Data.

(Read by Mr. Schiflett at Chicago)

This paper suggests methods of interpreting gravity data gathered in two widely separated provinces. The first area considered is peninsular Florida where little seismic and geological information is available. The second area investigated is part of the Permian Basin of West Texas where, over a period of years, considered geological and other information has been developed.

25. HERBERT DAWSON, Petty Geophysical Engineering Company.

The Planning of a Foreign Geophysical Operation.

(Read by Mr. Dawson at Chicago and Houston)

Discussion is made on the advance preparation necessary for a properly conducted foreign geophysical operation, with reference also to the economic facts involved which emphasize the necessity of having proper equipment and an efficient supply system.

26. E. F. STRATTON, Exploitation Manager of Schlumberger Well Surveying Corp.

Use of Electrical Logs for Quantitative Fluid Content Determinations.

(Read by W. J. Gillingham at Chicago and by Dr. Stratton at Houston)

27. MAURICE EWING, Woods Hole Oceanographic Institution.

Underwater Prospecting.

(Read by Dr. Ewing at Chicago)

PAPERS READ BY TITLE

28. W. R. MITCHELL, Vice-President, National Geophysical Company, Inc.
F. P. WIPFF, Senior Engineer, National Geophysical Company, Inc.

Q Meter for Low Frequency Reactor Measurements.

A direct reading Q meter is described which permits the determination of Q and inductance over a frequency range of 10-1,000 cycles, and a voltage range of 2-10,000 millivolts. The instrument is particularly well adapted to the measurements of reactors and transformers used in geophysical equipment. The theory of operation of the Q meter is given and some of the precautions which must be observed are discussed. The schematic diagram and photographs of the instrument are included and some of the more important constructional details discussed.

29. R. L. CONGDON, Research Engineer.

The Design and Testing of a Versatile Dynamic Seismometer.

The theoretical results of the preceding companion paper are used to produce a dynamic seismometer capable of being easily changed to various conditions of response. The frequency of maximum response and sharpness of response of the seismometer are variable independently, with the instrument's electrical impedance remaining fixed. Methods used in testing this seismometer from initial magnetic measurements to final field testing are discussed.

30. GLENN J. BAKER, Geophysicist, William M. Barret, Inc.

Dimensions and Units of Electromagnetic Quantities.

A brief history is given of the confusion in the literature in regard to c.g.s. electromagnetic units and some inconsistencies are pointed out. It is contended that most geomagnetic measurements are of the flux density B rather than of H, and that the gamma is correctly regarded as equivalent to 10^{-5} gauss. Dimensions of the important electromagnetic quantities and the numerical relations between m.k.s. units and electromagnetic and electrostatic c.g.s. units are set forth. The adoption of m.k.s. units is urged as they are particularly advantageous to engineers.

31. H. M. EVJEN, Vice-President, Elflex Company.

W. B. LEWIS, President, Elflex Company.

Further Experimental Proofs of Working Depths for Low-Frequency Commutated Currents.

Measurements of the potential existing during the current gap interval were made at four frequencies and with three electrode spreads. The electrode pattern was a Wenner Spread with electrode separations of 500, 1,000, and 1,500 feet for successive runs. The mid-point of the three spreads was the same. For each spread readings were taken at .32, .64, 1.28 and 2.56 cycles per sec. The commutator was adjusted to allow current to flow for 72 degrees, and to measure the potential during a 72 degree interval. (Cf.) Working Depths for Low Frequency Commutated Currents, GEOPHYSICS 10, 1, 63 (Jan. 1945). Direct current measurements were also made at each separation. The depth to the interface responsible for the main perturbation potential was computed for the direct current measurements; and a shallowest depth to the interface responsible for the gap-potential measurements was determined.

At two locations, one on and one off production, measurements were made at 24 frequencies between .32 and 2.56 cycles per sec. These data were fitted with theoretical curves based on three reflecting horizons. The effect from the horizon corresponding to the depth to present production is seen to be chiefly responsible for the difference in response at the two stations.

32. C. Y. FU, Consulting Research Geophysicist, United Geophysical Company.

Studies of Seismic Waves; Propagation of Elastic Waves in the Neighborhood of a Free Boundary.

Continuous and spherical harmonic waves are generated at an internal point of the medium. By use of the classical method of Lamb and Sommerfeld, the dif-

ferent modes of propagation near a free surface after the arrival of the waves are studied. From the approximate evaluations of the integrals, it is found that in addition to the ordinary types of surface and body waves, there are also inhomogeneous waves and surface waves which are not of the Rayleigh type. The amplitude factors of these latter waves vary inversly as the square of the focal distance instead of as the square root. Altogether, there are not less than five different types found and they are obtained from the asymptotic expansions and the singularities of the integrals.

33. R. MAURICE TRIPP, Assistant to the President, Geotechnical Corporation, Research Laboratory.

CHARLES C. O'BOYLE, Research Geophysicist, Geotechnical Corporation, Research Laboratory.

Beta Activity of Some Carbonaceous Materials.

The interest in radioactivity logging of sedimentary bore holes and the implications of research on the relation between radioactivity, organic content of sediments, and the origin of petroleum stimulated the quantitative determination by a rapid, routine method the activity of several samples of pollen, oil shales, carbonaceous shales, and bituminous material. Explanations are proposed to account for the wide variations and the significance on the origin of petroleum.

34. ALFRED WOLF, Geophysical Research Corporation.

Electric Field of an Oscillating Dipole on the Surface of a Two-Layer Earth.

Fomulae are derived for the electric field of a low-frequency oscillating dipole placed on the surface of a two-layer earth; the method differs but little from those employed by Riordan and Sunde (Bell Syst. Tech. Jour. 12, 1933, p. 162). The electric field is given in terms of Bessel function integrals which can not be evaluated readily in the general case. Two special cases are treated in detail, namely, one in which the conductivities of the two layers representing the earth have nearly the same value, and one in which the lower layer is a perfect insulator. Equations are derived in these two cases which are adapted for numerical calculation; in the case of an insulated layer, the discussion is limited to terms of the first order in frequency.

35. D. M. CHOATE, Geologist-Geophysicist, Atlantic Refining Company.

O. C. CLIFFORD, JR., Chief Geophysicist, Atlantic Refining Company.

Seismic Surveys of Neale Field, Beauregard Parish, Louisiana.

Reflection-seismic exploration of an area in Beauregard Parish, Louisiana, was initiated in February, 1938, and was first completed in October, 1938. As a result of shallow structural determination, a test well (dry) was bored. This test was followed by additional seismic work which showed the position of the structure shifted with depth and resulted in the completion of the discovery well in March, 1940. Additional seismic data were added at various times, and the area of probable structural closure, to depths in excess of 11,000 feet, was eventually considered evaluated by the method in October, 1944.

OFFICERS FOR THE YEAR ENDING APRIL, 1947

HENRY C. CORTES, Past President

CECIL H. GREEN, Vice-President

J. J. JAKOSKY, President

GEORGE E. WAGONER, Secretary-Treasurer

L. L. NETTLETON, Editor

MINUTES

ANNUAL BUSINESS MEETING

April 1, 1946

The annual Business Meeting of the Society of Exploration Geophysicists was held in the North Ballroom, on the third floor of the Stevens Hotel, Chicago, Illinois. The meeting was presided over by President Cortes and was called to order at 9:20 A.M.

Mr. Cortes expressed appreciation for the Society to Dr. Jakosky, Program Chairman, and to all of the regional program committees for their extra efforts put forth in obtaining a fine aggregation of papers for the technical sessions of the present annual meeting; and to Mr. Ira Cram for his valued time and effort as advisory member of the Chicago Arrangements Committee in directly handling the many details with the Stevens Hotel.

The minutes for the Annual Business Meeting for 1945 were read by the Secretary and accepted. The Treasurer's Report for 1945 was then read and accepted. The Secretary-Treasurer included a membership report, as follows:

	1,945	*1944*	*1943*
Active	1,072	934	
Associate	183	189	
Student	5	7	
Honorary (Living)	3	3	
Totals	1,263	1,135	1,004
Increase over prior year	130	129	—

Incidentally, our living honorary members are: E. L. DeGolyer, L. Mintrop, and Wallace E. Pratt. The rank of student membership has been apparently well nigh overlooked to date—as evidenced by the fact that we have only five in this category. It would seem appropriate for the next Executive Committee to consider the idea of encouraging student membership through more direct approach.

It is interesting to note that included in the grand total of 1,263 members, there are 446 members who are also members of the American Association of Petroleum Geologists. That is, one in every three is a joint member.

Dr. Nettleton was next called upon for the Editor's Report, in which he included the following points:

(a) Technical material, both on hand and committed, comprises a satisfactory amount for the next year of GEOPHYSICS.

(b) The status of Volume I of the proposed Case Histories Series is indicated by the fact that papers previously published in GEOPHYSICS, as well as those obtainable from the Journals of A.A.P.G. and A.I.M.M.E., provide enough material for only approximately one-half the volume. Thus the need for many additional historical papers is clearly indicated.

(c) To avoid delays in preparing their papers for publication, authors are urged to give a little more attention to the form of their manuscripts, maps, and illustrative matter. Suggestions have recently been presented by the Editor in GEOPHYSICS—refer to Vol. X, No. 3, page 421.

President Cortes then read the election results for officers for ensuing year. Votes case by usual mail ballot were compiled as follows:

President		*Vice-President*		*Secretary-Treasurer*	
Jakosky	421	Green	478	Wagoner	377
Macelwane	268	Heiland	211	Jackson	301

Messrs. Jakosky, Green, and Wagoner were therefore formally declared elected. A total of 731 votes were cast, of which 35 were invalid for delinquency in dues and 2 for being too late.

There being no further business, the Annual Business Meeting of the Society was adjourned at 9:50 A.M.

CECIL H. GREEN, *Secretary*

ANNUAL REPORT OF THE SECRETARY-TREASURER OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS

BALANCE SHEET
SOCIETY OF EXPLORATION GEOPHYSICISTS—DALLAS, TEXAS
December 31, 1945

ASSETS

Current			
Cash			
In Banks		$12,178.53	
Accounts Receivable			
Membership Dues	$532.50		
Advertising	386.25		
Back Numbers	99.60		
Reprints	47.99		
Subscriptions	15.50	1,081.84	$13,260.37
Investment			
Farm and Home Savings and Loan Association of Missouri—Fully Paid Certificate		5,000.00	
U. S. Savings Bonds		7,960.00	12,960.00
Office Equipment			
Cost		72.67	
Less: Reserve for Depreciation		28.12	44.55
			$26,264.92

LIABILITIES

Current			
Accounts Payable			
For Expenses, etc.		415.24	
Withholding Tax		125.86	
Salary Accrued		625.00	1,166.10
Deferred Income			
Prepaid Dues		168.00	
Prepaid Advertising		10.00	
Prepaid Subscriptions		656.63	834.63
Surplus			
Balance January 1, 1945		20,960.19	
Add			
Increase Year Ended December 31, 1945—Per Statement of Income and Expense		3,304.00	24,264.19
			$26,264.92

Income and Expense
Society of Exploration Geophysicists—Dallas, Texas
Year Ended December 31, 1945

INCOME				
Membership Dues:				
Current		$6,138.00		
Reinstatements		38.00	$6,176.00	
Publications:				
Advertising	$4,366.50			
Subscriptions	1,646.67			
Back Numbers	749.00			
Reprints	213.60	6,975.77		
Less: Discounts		279.60	6,696.17	
Other Income:				
Interest Received		217.38		
Commissions on Publications		5.00	222.38	$13,094.55
COSTS AND EXPENSES				
Publication Costs:				
GEOPHYSICS:				
Vol. X No. 1—172 Pages	$1,147.86			
No. 2—228 Pages	1,307.43			
No. 3—137 Pages	1,341.10			
No. 4—104 Pages	1,092.10	4,888.49		
Reprints		302.10	5,190.59	
Expenses—Per detail schedule			4,599.96	9,790.55
Excess of Income over Costs and Expenses				$ 3,304.00
EXPENSES				
Salary—Business Manager				$ 1,500.00
Commissions:				
Advertising:				
Business Manager		$ 716.63		
Agencies		462.18	$1,178.81	
Subscriptions, etc.—Agencies			48.55	1,227.36
Annual Meeting				641.04
Postage and Box Rent				198.51
Stationery, Office Supplies, and Expenses				438.51
Freight and Express				37.24
Bad Debts				73.98
Auditing				270.00
Telephone and Telegraph				115.14
Bond Premiums				42.50
Professional Card				30.00
Depreciation				23.87
Bank Charges				1.76
				$ 4,599.96

Respectfully submitted,
CECIL H. GREEN, *Secretary-Treasurer*

THE GEOPHYSICAL CASE HISTORIES VOLUME

The publication of a volume of Geophysical Case Histories has been under consideration for some time by the Executive Committee of the Society. Definite action authorizing this project was taken at the Committee meeting in Chicago in April. The Editor was asked to form a special Editorial Committee to assist in the selection and preparation of papers to be included in the volume. The following members of the Society have agreed to serve on this Committee:

Henry C. Cortes, Magnolia Petroleum Co., Dallas (Chairman)
L. F. Athy, Continental Oil Co., Ponca City
A. B. Bryan, Cortes Oil Co., Tulsa
Kenneth Burg, Stanolind Oil & Gas Co., Tulsa
E. D. Alcock, National Geophysical Co., Dallas
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Frank Goldstone, Shell Oil Co., Houston
H. J. Hintze, Phillips Petroleum Co., Bartlesville
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J. W. Hoover, The California Co., New Orleans
J. C. Karcher, Continental Bldg., Dallas
Joseph A. Sharpe, C. H. Frost Gravimetric Surveys, Tulsa
Henry Salvatori, Western Geophysical Co., Los Angeles
Louis A. Scholl, The Texas Co., Houston
L. O. Seaman, Sinclair Prairie Oil Co., Tulsa
D. C. Skeels, Standard Oil Co. of N. J., New York
L. H. Waterfall, Union Oil Co. of California, Los Angeles
B. B. Weatherby, Geophysical Research Corp., Tulsa
Paul Weaver, Gulf Oil Corp., Houston
G. H. Westby, Seismograph Service Corp., Tulsa

PRELIMINARY ANNOUNCEMENT
1947 ANNUAL MEETING

The 1947 annual meeting of the Society of Exploration Geophysicists will be held in Los Angeles, California, in conjunction with the annual meetings of the A.A.P.G. and S.E.P.M. Tentative arrangements have been made for headquarters at the Biltmore Hotel during the period of March 24 to 27.

This advance announcement is made in order to encourage the earliest start in preparation of papers for the meeting and for later publication in GEOPHYSICS. The following committees have already been appointed with a view to making arrangements and for securing technical material.

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Walter Hohag, General Petroleum Corp., Casper, Wyoming
Harry L. Thomsen, Shell Oil Company, Casper, Wyoming

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Milton B. Dobrin, Naval Ordnance Laboratory, Washington, D. C.
Maurice Ewing, Columbia University, New York, New York

ANNOUNCEMENT OF NEW SPECIAL COMMITTEES OF THE SOCIETY OF EXPLORATION GEOPHYSICISTS

At the meetings of the Executive Committee of the Society last April, several new special committees were authorized. Chairmen of these committees have been appointed by the President, and these chairmen have now reported their committee members.

Student Membership—(A committee to inform under-graduate and graduate students on the nature of applied geophysics as a positive means of increasing enrollment in special grade of student membership).

Ralph S. Jackson, Independent Exploration Co., Houston, Chairman
Dave P. Carlton, Humble Oil and Refining Co., Houston
Milton B. Dobrin, Naval Ordnance Laboratory, Washington, D. C.
John H. Hodgson, University of Toronto, Toronto, Ontario, Canada

Paul L. Lyons, Carter Oil Company, Tulsa
James C. Menefee, Magnolia Petroleum Company, Dallas

Best Paper Award—(A committee to select the best paper received over a one-year period and to recommend an appropriate annual award).

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Frank Goldstone, Shell Oil Co., Inc., Houston
M. King Hubbert, Shell Oil Co., Inc., Houston
Frederick E. Romberg, LaCoste and Romberg, Austin
Paul Weaver, Gulf Oil Corp., Houston

Geophysical Education—(A committee to assist in giving to educational institutions and to other professional societies advice and guidance in setting up and conducting geophysical curricula).

James B. Macelwane, S.J., St. Louis University, St. Louis, Chairman
Perry Byerly, University of California, Berkeley, California
Maurice Ewing, Columbia University, New York
Beno Gutenberg, California Institute of Technology, Pasadena, Calif.
C. A. Heiland, Heiland Research Corp., Denver, Colorado
M. King Hubbert, Shell Oil Co., Inc., Houston
D. C. Skeels, Standard Oil Co. of New Jersey, New York

PERSONAL ITEMS

SAM ZIMMERMAN, for some years with the Carter Oil Company, has been transferred to the Standard Oil Company of Egypt, as chief geophysicist. His address will be in care of that company, 22 Sharia Kasr El Nil, Cairo, Egypt.

GLENN M. MCGUCKIN, formerly with the Magnolia Petroleum Company, is now owner and operator of the Reliable Geophysical Company, P. O. Box 1111, Corpus Christi, Texas.

DR. L. L. NETTLETON, for the past eighteen years in charge of gravity interpretation for Gulf Research & Development Company, and the present Editor of GEOPHYSICS, has become a partner in the firm, Gravity Meter Exploration Company, where he will be in charge of the interpretation of gravity data and writing of reports. Editorial matter for GEOPHYSICS should now be addressed to 1348 Epserson Building, Houston 2, Texas.

WILLIAM T. HOLSER, recently welcomed into the Society membership, is working with the U. S. Geological Survey at Wrangell, Alaska, this summer. This fall, he will be Lecturer in Geology at Columbia University, and may be addressed: Department of Geology, Columbia University, Morningside Heights, New York 27, N. Y.

LT. COL. ROBERT W. JACKSON, of Dallas, Texas, has been appointed Post Signal Officer at Fort Sill, Oklahoma. Col. Jackson, who was formerly a geophysicist with the Geophysical Service, Inc., of Dallas, was radio officer in Headquarters signal office, Philippine Department, on Pearl Harbor Day, and in April, 1942, was among those captured on Bataan. He was held in prison camps in the Philippines and in Japan for 41 months, being released in September, 1945.

GEORGE B. KAISER (Lt. Col. A.C.) has left Washington, and may be addressed at Box 574, Wharton, Texas.

J. L. KEZELER, formerly with Seismograph Service Corporation, is now President of Key Velocities, Inc., Box 1824, Tulsa, Oklahoma.

W. E. NOTLEY, assistant gravity meter supervisor for the Stanolind Oil and Gas Company, has his office now at 613 Amarillo Bldg., Amarillo, Texas.

ODELL C. OLSON, of the Oil and Gas Division of the Railroad Commission of Texas, has moved his office from Midland to Abilene, Texas.

L. J. PADDISON, who served during the war years in the Applied Physics Laboratory of the Johns Hopkins University, Silver Spring, Md., is now in the Research and Development Division of the New Mexico School of Mines at Albuquerque, New Mexico. His address there is Station A.

HENRY F. BIRKENHAUER, S.J., has transferred from West Baden College to the John Carroll University, University Heights, Cleveland 18, Ohio.

DR. H. H. BRONS, who, in 1941, was working in Balikpapon, Borneo, and who has spent the last three and a half years as a prisoner in a Japanese concentration camp in Java (N.E.I.), is resuming his position as geophysicist with the Bataafasche Petroleum Mijschaapij. After a brief visit in the States, he will return in July to that Company's headquarters, Carel van Bylandtlaan 30, The Hague, Netherlands.

In noting in the April issue the return of LOUIS C. PAKISER, JR., to civilian status, he was, through an unfortunate typographical error, accorded the rank of Captain. Mr. Pakiser asks that this be corrected at once. He is now back with his former company, as computer, and may be addressed c/o The Carter Oil Company, Box 801, Tulsa, Okla.

JULIAN K. PAWLEY, geologist with the Standard Oil Co. of Texas, has changed his residence address to 8142 Howard Drive, Houston 12, Texas.

J. D. BERWICK, formerly with the Imperial Oil Co. Ltd., of Toronto, is now Secretary-Treasurer of the Rocky Mountain Land & Leasing Corpn., Box 1478, Pueblo, Colorado.

PHIL P. GABY, former California supervisor for Geophysical Service, Inc., has joined Standard Oil Co. of California as Consulting Geophysicist. Gaby, who has worked in California since 1934, is a graduate of Southern Methodist University and did post-graduate work at the University of Texas. He will office in the Standard Oil Building, San Francisco, Calif.

PIERRE M. HONNELL (Lt. Col., S.C.), after five years in the army (four of them on the staff at West Point) has taken the position of associate professor of electrical engineering at the University of Illinois. His address is: Prof. Pierre M. Honnell, University Station Box 66, Urbana, Ill.

A. P. CRARY, formerly supervisor for the United Geophysical Company, S.A., in Caracas, Venezuela, is now located at Watson Labs.—A.M.C., WLERL-4, Red Bank, N. J.

MARION H. GILMORE, released from active duty as Lieutenant Commander in the Navy in March has been recalled as a geophysicist under Civil Service to direct the Navy's research work in using Microseisms to detect, tract, and locate hurricanes and typhoons in the Caribbean and in the Pacific. He may be addressed at 838 Dupont Building, Miami, Florida.

NEIL W. MANN received his discharge in April, after four years of active Army duty, and returned to his former company, Geophysical Service, Inc., as a Party Chief. His address is 1311 Republic Bank Bldg., Dallas, Texas.

EDWARD B. STOVER, JR., after three years' active duty with the U. S. Naval Reserve, has returned to the Stanolind Oil and Gas Company as Geophysical Research Engineer. His address is Box 591, Tulsa, Oklahoma.

J. R. MAXEY, formerly with Sohio, is now Senior Geophysicist for the United Geophysical Company of South America, with offices at Aptdo. 1085, Caracas, Venezuela.

JOHN E. MCDOUGALL has left the Louisiana Department of Wild Life and Fisheries, and is now with the Atlantic Refining Company, Lake Charles district. His address is 6203 Louis XIV St., New Orleans, La.

A. M. EICHELBERGER, JR., party chief for the United Geophysical Company, after six years in Brazil is being transferred to the United States in August. His address will be 1400 North Virginia Ave., Glendale 2, Calif.

LEO W. KONZ left the Carter Oil Company last year, and is now seismic computer for the Sun Oil Company. Recently he has been in Illinois, but his residence is at 1502 Central Drive, Beaumont, Texas.

DAN H. WOODARD is eastern supervisor for the Miller Geophysical Company, 1044 South Robertson, Los Angeles, Calif.

WILLIAM I. MAYFIELD (Ensign) was released from Navy duty in December, after two and a half years' service, and is now Geologist with the Continental Oil Co., Box 1800, Wichita Falls, Texas.

JAMES A. BALLARD has been relieved from active duty with the U.S.A.A.F., and has returned to the Seismograph Service Corpn., Kennedy Bldg., Tulsa 3, Oklahoma, as a Party Chief.

LAWRENCE K. MORRIS, for some time past with the United Geophysical Company at Punta Arenas, Chile, has returned to the States and may be addressed at that Company's headquarters, 595 East Colorado St., Pasadena 1, California.

BERNARDO GROSSLING-FREUDENBURG, recently at the California Institute of Technology at Pasadena, is now in South America at Casilla 2800, Santiago, Chile.

C. J. CHAPMAN has been transferred to the Calgary office of Imperial Oil Ltd., and may be addressed at 1021 Nineteenth Ave. N.W., Calgary, Alta., Canada.

ETHEL WARD MCLEMORE has left the United Geophysical Company of Pasadena, California, and returned to Texas to work on a publication. Her temporary address is 4515 Highland Drive, Dallas, Texas.

PETER JACOBSEN, JR., who has been with the Carter Oil Company at Rock Springs, Wyoming, has gone with the Creole Petroleum Corpn. at Caracas, Venezuela.

MERLE C. BOWSKY (Lt.-Col.) has abandoned his A.P.O. address, and is back with the Lane-Wells Company, this time with their Houston division, as Radioactivity Engineer. He may be addressed at Box 1407, Houston, Texas.

JAMES L. MORRIS is currently located at Billings, Montana, Box 1608.

CHARLES E. DAY has moved from Cincinnati, Ohio, to Tulsa, Oklahoma, where he may be addressed c/o Geophysical Research Corpn., 2607 N. Boston Place.

R. B. ROSS, Geophysicist with the Gulf Research & Development Corpn., has moved from the Pittsburgh office to Box 661, Tulsa, Oklahoma.

J. J. H. JANSEN, M., formerly at Larchmont, is now located in Rye, N. Y., care of U. C. YOUNG, Kenilworth Road.

The Carnegie Institution of Washington announces the retirement on June 30, 1946, of *Dr. John A. Fleming* from the Department of Terrestrial Magnetism, of which he has been Director since 1935 and a member of its scientific staff since 1904. He will be succeeded by *Dr. M. A. Tuve,* Chief Physicist, who joined the scientific staff of the Department in 1926.

Dr. Fleming will be temporarily located at the Carnegie Institution of Washington at its Office of Administration, 1530 P Street, N.W., Washington 5, D. C. (Room 313, Telephone DUpont 6400), as adviser to the Institution in governmental and international scientific relations.

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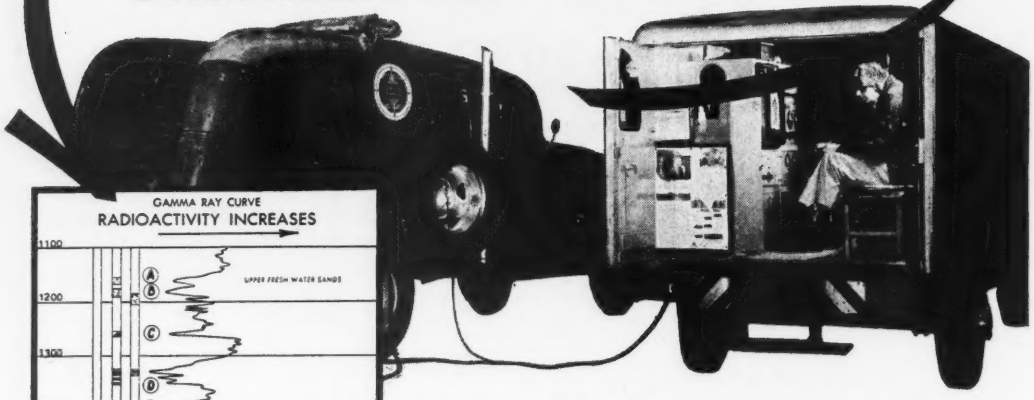

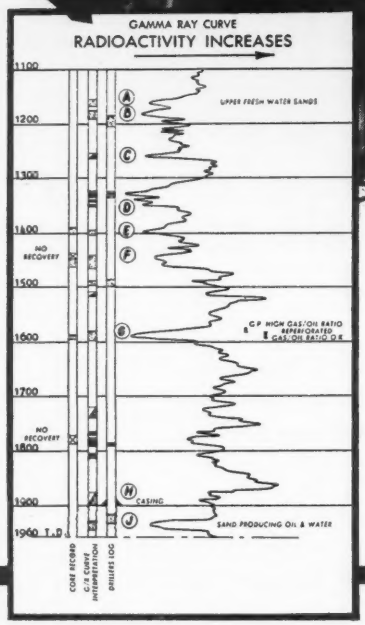

Here is some of the important information shown on a Radioactivity Log that can be profitably used by oilwell operators.

1. The location of upper, cased-off, potential producing zones where no, or doubtful, information exists.
2. The location of the top of a producing zone for bottom water shut-off.
3. The location of upper sands for salt water disposal.
4. The supplying of additional information where cores were missed, not completely recovered, or lost.
5. The correction of earlier drillers logs.
6. The location of upper potential fresh water sands.
7. The location of the top and bottom of an oil producing zone for gas-oil ratio control.

Check the Gamma Ray Log at the left against the well records. See for yourself how the Radioactivity Log completes the well information.

Tomorrow's Tools—Today!

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Check these Points

Illustrated here from left to right is the platted core record of the well logged, a skeleton graphic interpretation of the log, a skeleton drillers log of the well and the Gamma Ray curve of the well. Letters correspond with letters on the log at the point where the following information is shown:

A. Gamma Ray indicates potential fresh water sand not cored nor logged by driller.

B. Gamma Ray locates top of sand considerably higher than sand logged by driller.

C. Gamma Ray locates shaley sand not cored nor logged by driller.

D. Gamma Ray locates thin sand stringer not cored nor logged by driller.

E. Gamma Ray locates top of sand several feet lower than shown on core record.

F. Gamma Ray locates top of sand which was not recovered in the core.

G. Gamma Ray locates top of producing zone considerably higher and thicker than on the core record. With this information the upper perforations were squeezed off and perforations made lower to reduce gas-oil ratio.

H. Gamma Ray locates sandy shale just above casing seat that may be worthy of a production test before abandonment.

J. Gamma Ray locates top and bottom of main producing sand considerably lower than drillers measurement which will allow more accurate plug back to shut off water.

QUALITY EXPERIENCE DEPENDABILITY

* *Quod erat demonstrandum (Which was to be demonstrated)*

The many successful drilling operations which have resulted from Petty geophysical surveys, in fields throughout the world during more than the last two decades, demonstrate the value of our background of broad experience, advanced geophysical equipment, accurate interpretations and expert crews in obtaining authentic subsurface data on which to formulate drilling plans.

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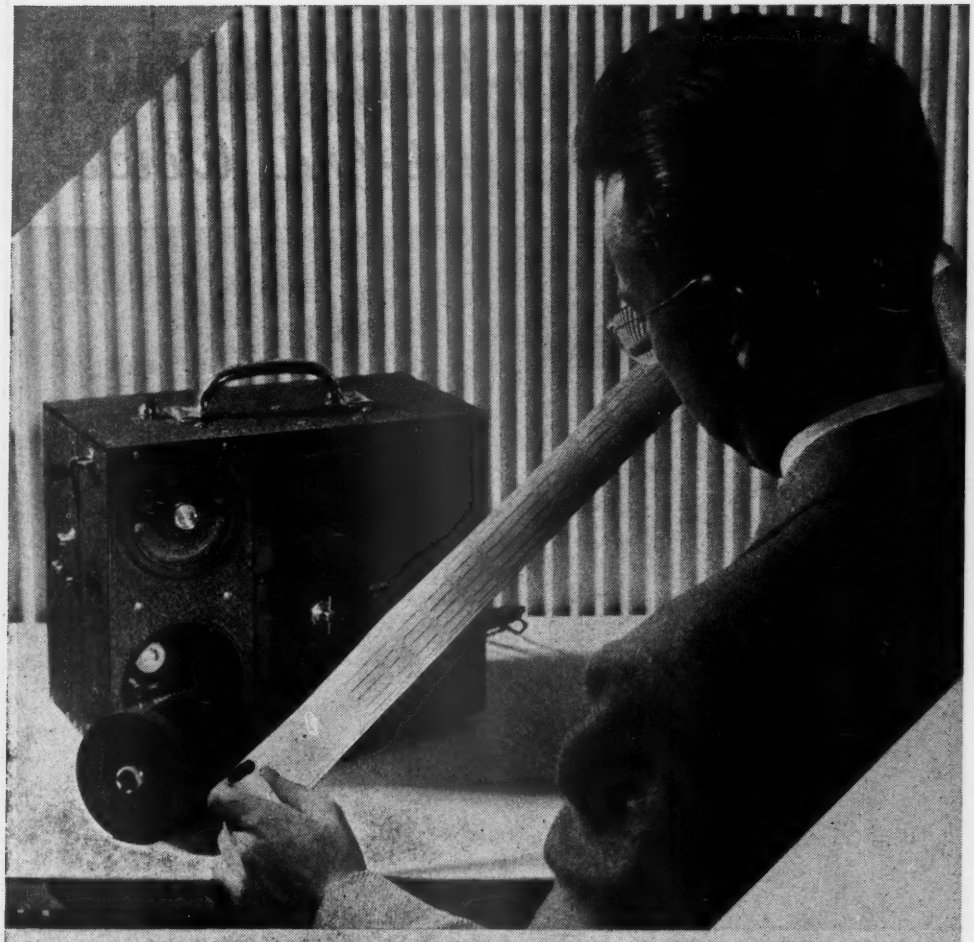

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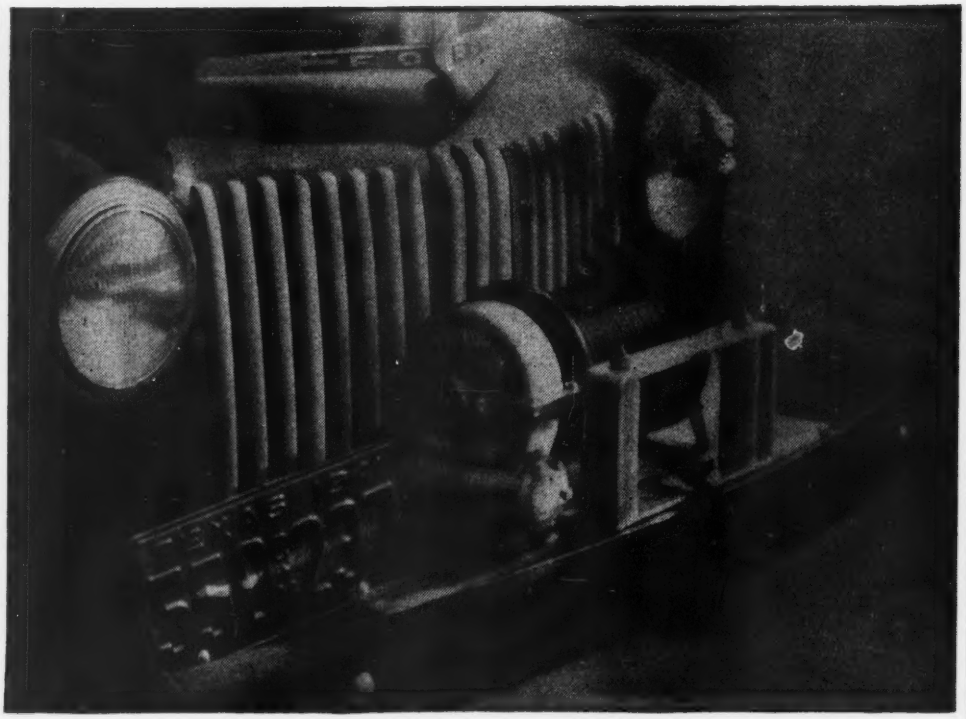

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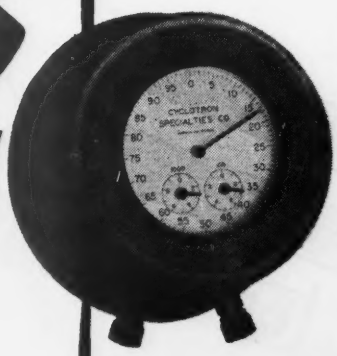

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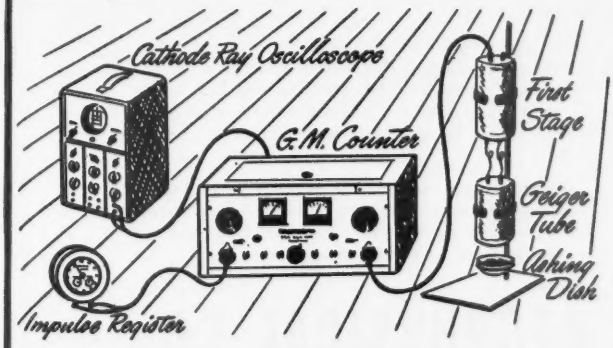

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ANNOUNCEMENT

is made of the opening of a permanent business office for the Society, with Mr. C. C. Campbell as Business Manager, effective July 15, 1946. All correspondence other than editorial matters (Dr. L. L. Nettleton, Editor, 1348 Esperson Bldg., Houston 2, Texas) should be addressed to

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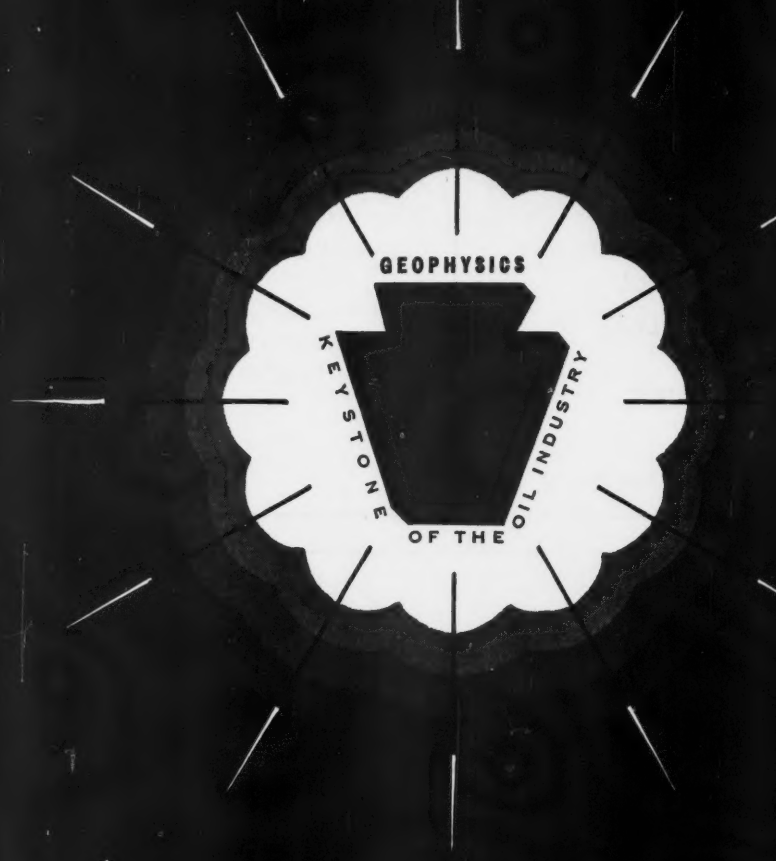

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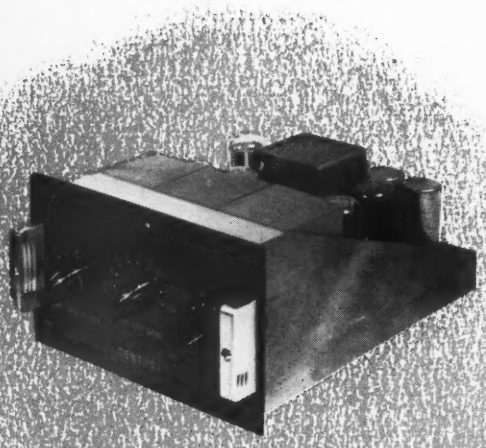

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Years of intense engineering have created the most mode amplifier in its field.
Particular emphasis has been paid to field operational pro lems to insure maximum stability, freedom from cross-fe and instrument failure.
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3. Variable Filters - 2 High Pass 1 Low Pass
4. Variable Selectivity
5. Constant dual rate automatic gain control
   a. Operating range - 80 D.B.
   b. Fast operate time - 900 decibels per second
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   d. Operate times constant regardless of the average signal level
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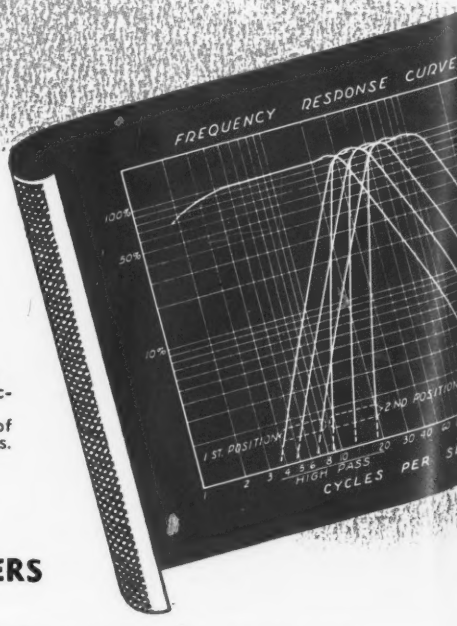
14. 12 Volt System



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25 trace element weighs 3 1/2 pounds.

Century is the world's largest manufacturer of this type galvanometer.

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The Century 0-45-2 oscillograph using our tubular galvanometers produces vivid black on white records on paper widths from 2" to 8". A light weight, precision made instrument, it is designed for maximum service. Timing is obtained by means of a vacuum tube driven fork and synchronous motor. Magnetically coupled, there are no contacts, buttons, or other devices to cause timing failure. The fork will maintain frequency to an accuracy of 5 x 10-6 under temperature changes of 0°F to 160°F. Viewing of spots is accomplished by means of an elaborate prismatic viewing screen.

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Output attenuators can be installed on the oscillograph for ease of operation.

SIZE: 10 1/2" high, 10 1/2" deep, 20" long.

WEIGHT: Approximately 62 lbs.

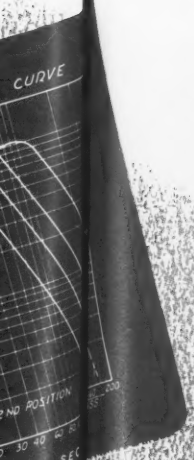
PAPER WIDTH: 2" to 8".

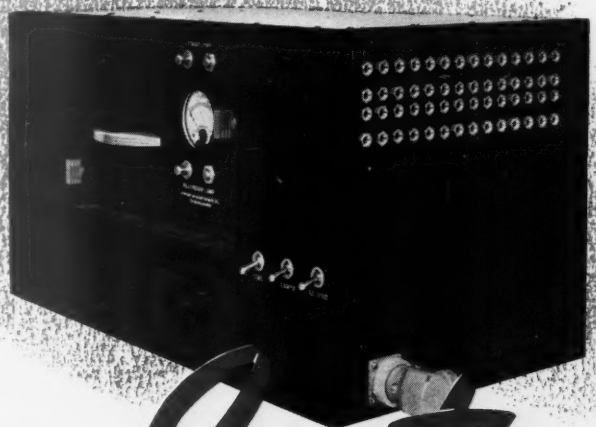
MAGAZINE CAPACITY: 200'.

12, 14, 24, or 28 galvanometer elements as desired.

Three optional paper speeds.

Fully automatic in operation.





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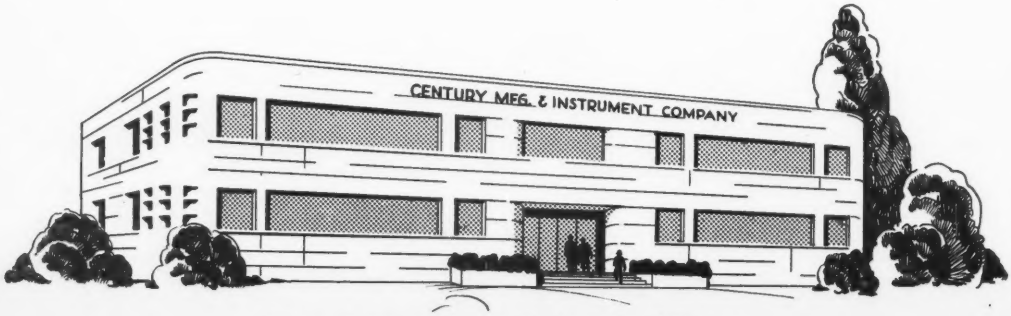

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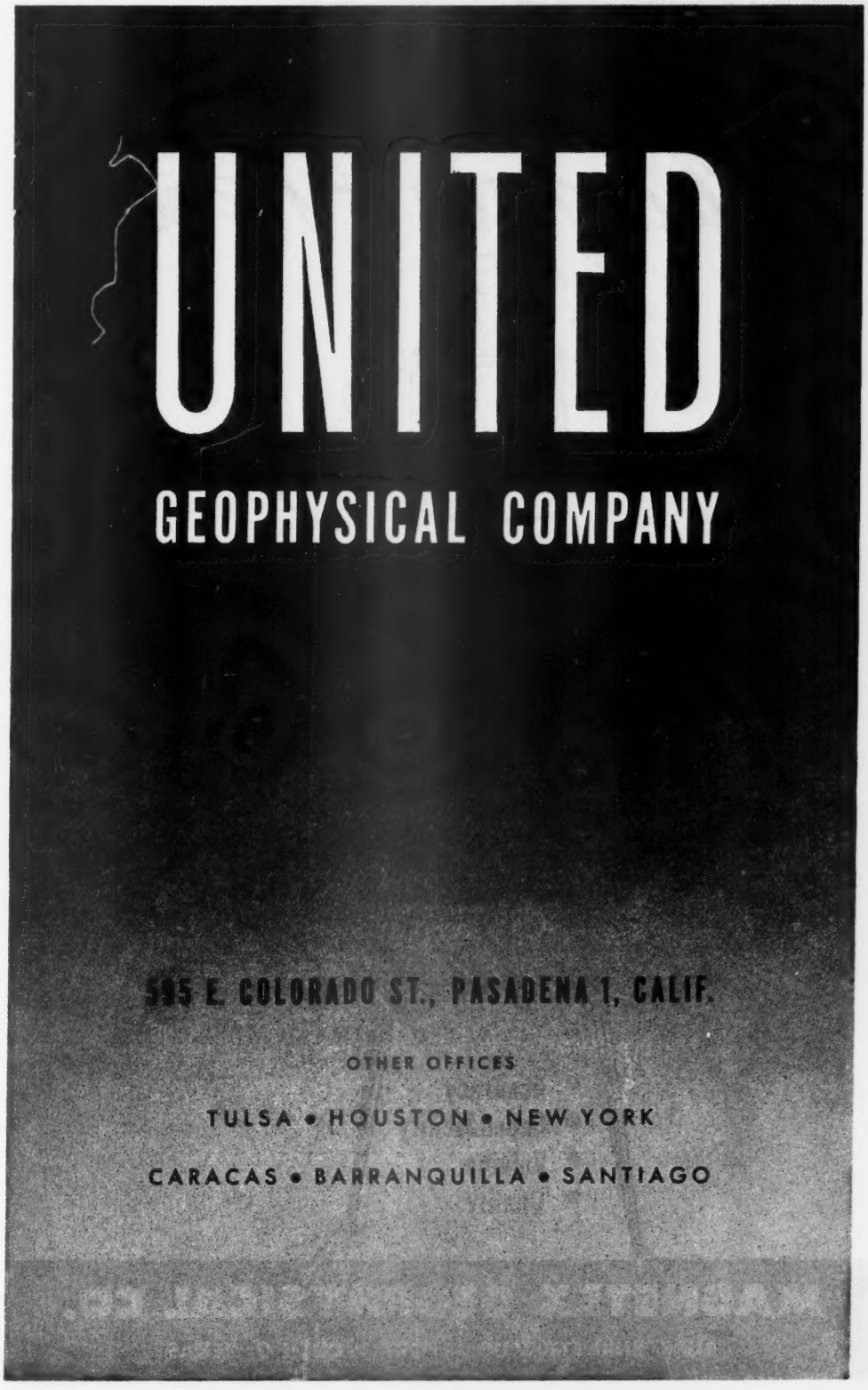
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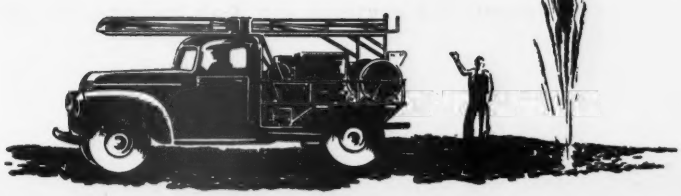

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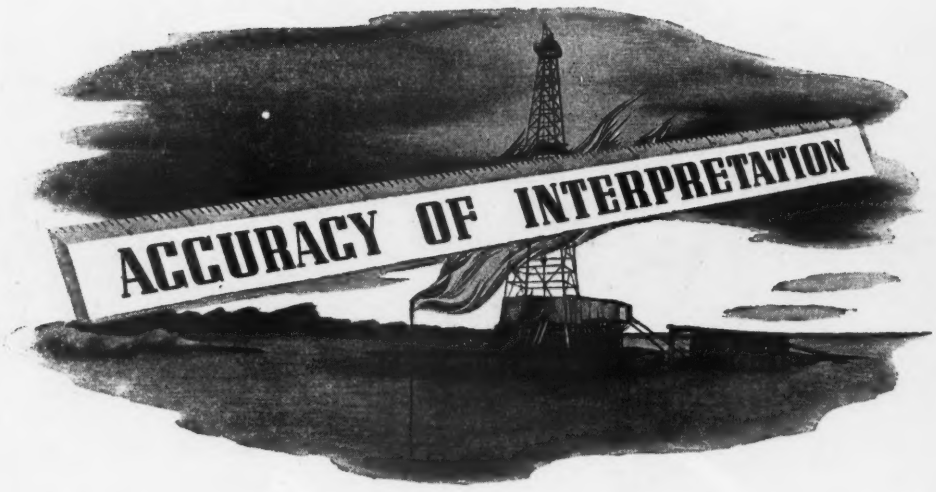

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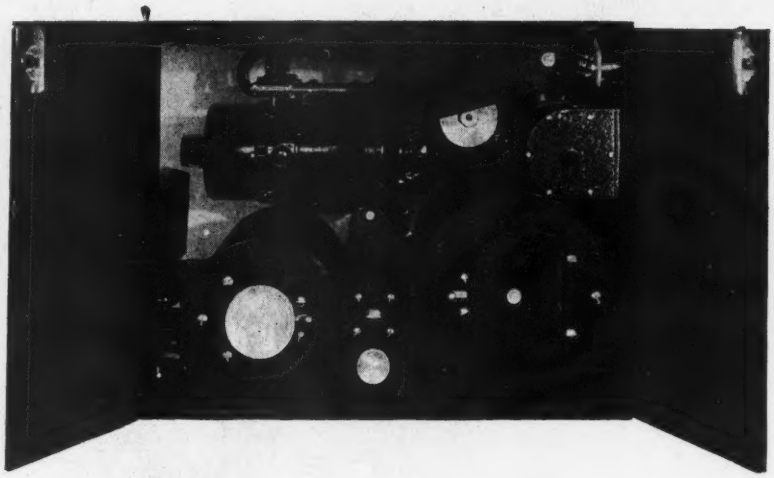

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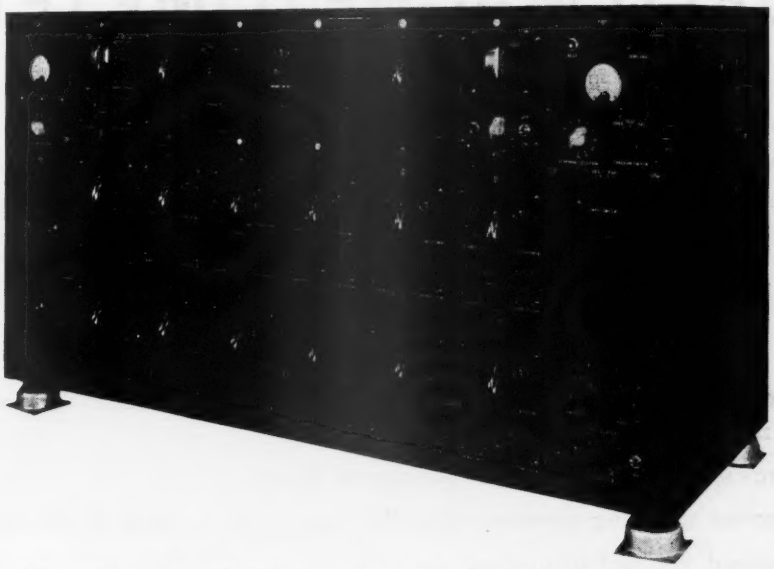

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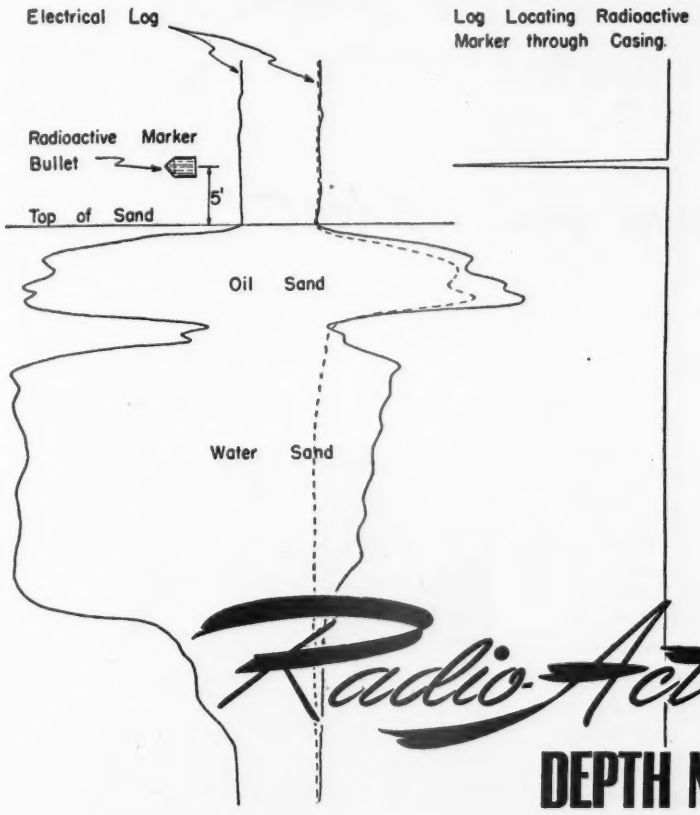

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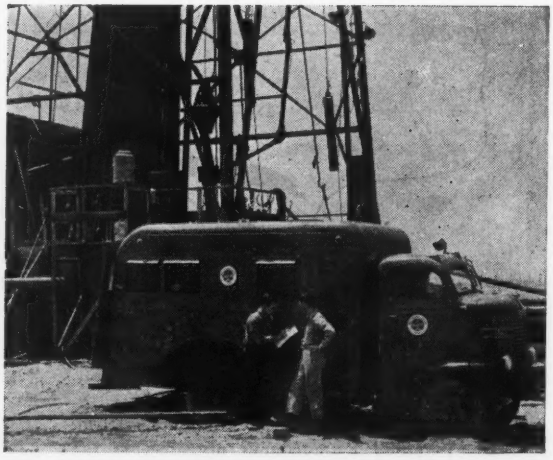

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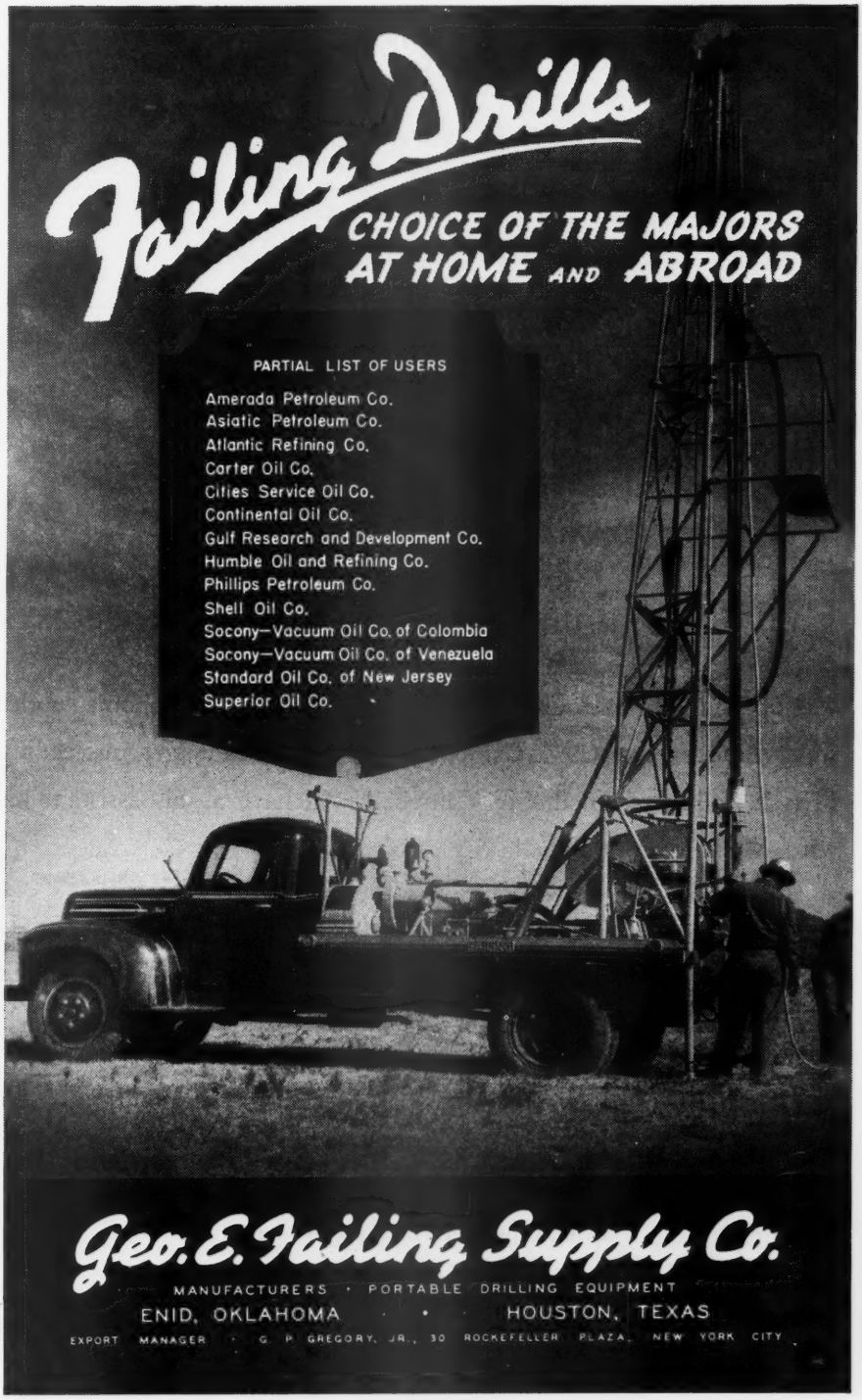
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Editorial matters should, as formerly, be addressed to Dr. L. L. Nettleton, whose address has recently been changed to 1348 Mellie Esperson Bldg., Houston 2, Texas.

All other correspondence should be directed to the attention of the Business Manager.

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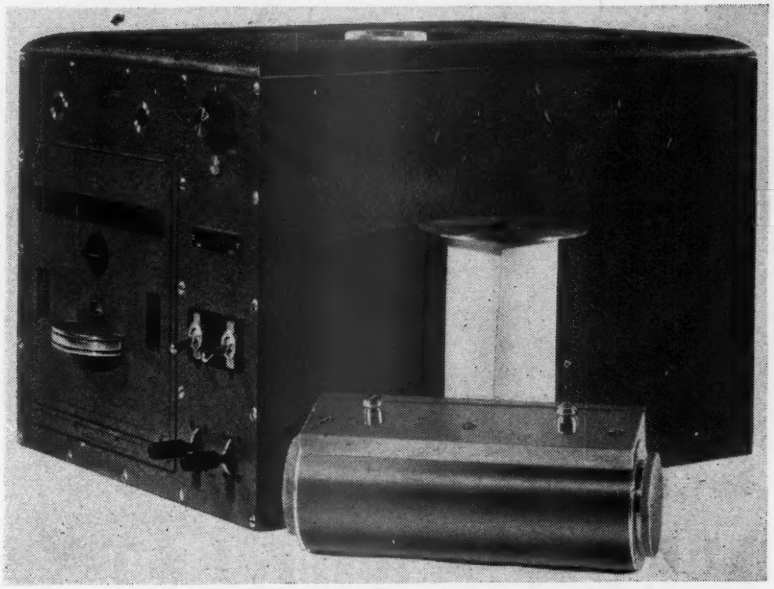

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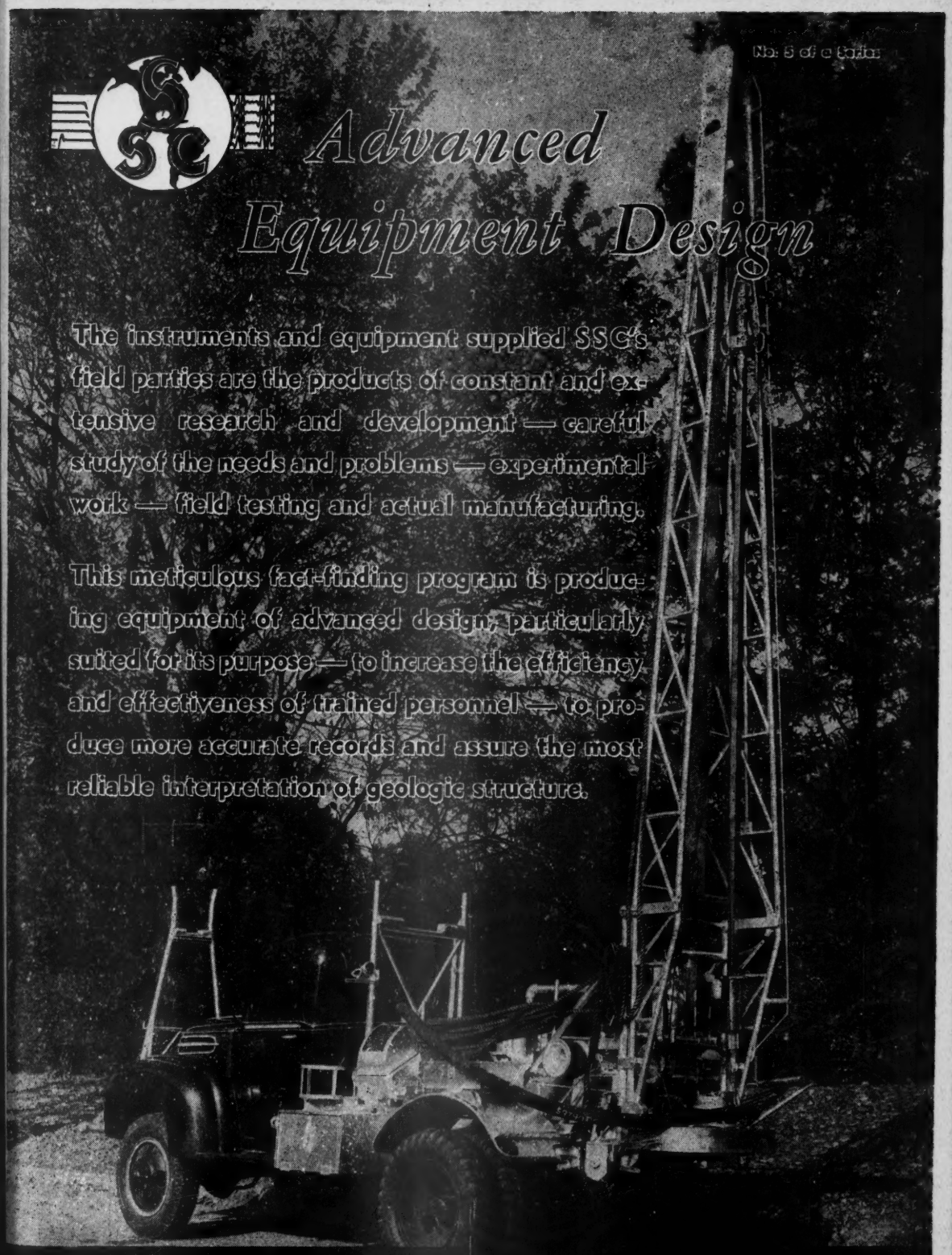
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